UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1407

Washington, D. C. ▼ April, 1926

SOME RESULTS OF SOFT-PORK INVESTIGATIONS

Conducted jointly by the
UNITED STATES DEPARTMENT OF AGRICULTURE
and the
AGRICULTURAL EXPERIMENT STATIONS
of

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Statement of Supervision and Authorship

This bulletin is a report on the results of cooperative soft-pork investigations for a period of five years, from July 1, 1919, to June 30, 1924. The investigations are being continued. The results reported were obtained under the direction of the following:

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Credit is due L. W. Himmler[1] and H. S. Isbell,[1] of the Bureau of Animal Industry, for assistance in the laboratory work, and to K. F. Warner, of the Bureau of Animal Industry, for supervision of the slaughtering at the United States Experiment Farm, Beltsville, Md.

By cooperative agreement the results of the investigations are shared jointly and equally by participating institutions. Each cooperating State is authorized also to publish this report in full or in part as a State bulletin with supplementary data, if desired, relative to the local phases of the soft-pork problem, giving due credit to this publication.

[1] Resigned.

[2] Data from a few "check" pigs only from the Arkansas and Tennessee stations are included in this bulletin. Both stations, however, have conducted work, furnishing considerable data along other lines which will be reported in subsequent publications.

SOME RESULTS OF SOFT-PORK INVESTIGATIONS

Prepared by

O. G. Hankins, *Associate Animal Husbandman*, and N. R. Ellis, *Associate Biological Chemist, Animal Husbandry Division, Bureau of Animal Industry*, in consultation with those named on the preceding page as responsible for the work

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THE SOFT-PORK PROBLEM

Much has been said and written with reference to the undesirable characteristics of the products from soft hogs. Generally speaking,

Fig. 1.—Fresh hams from oily and hard carcasses

their inferiority to the products of firm hogs is recognized. In recent years an effort has been made by some firms, however, to show that certain products from oily [3] hogs, particularly the hams, when cured by special processes, were superior to those from firm hogs (fig. 1). It seems that there is less reason for discrimination against the hams than against any of the other products of soft hogs. The explanation is found in the fact that ordinarily the ham carries a relatively small proportion of fat, in which the softness lies. Green hams constitute, however, only about 18 per cent of the weight of the dressed carcass. The bacon, shoulders, loins, lard, and sausage re-

[3] Oily hogs differ from soft hogs only in degree of softness. The oily class is the softest in the scale of physical grades.

main to be disposed of, and it is in the handling, sale, and use of these parts in competition with the same products from firm hogs that the real difficulties lie.

Generally speaking, the smoked products from soft and oily hogs lack firmness and usually present a greasy, unattractive appearance. In many instances fluid fat drips from such meat, especially in warm weather.

Soft bacon (fig. 2) is difficult to slice. Fresh pork from a soft carcass is soft, flabby, shapeless, and difficult to handle. Furthermore, if from a carcass classed as oily the fresh cuts are oily and greasy. Lard (fig. 3) from soft hogs lacks body, and when derived from oily carcasses is usually fluid at ordinary refrigerator temperatures. The sausage (fig. 4) is greasy and mushy, packs together too readily, and is unpleasant to handle. It will not hold its shape in retail packages or in cakes for frying. These few facts make it evident that, as a whole, the products of soft hogs are not so desirable as those of firm hogs.

FIG. 2.—Fresh bacon from oily and hard carcasses

ECONOMIC ASPECTS OF THE PROBLEM

Feed is generally recognized as the principal cause of soft pork. If certain feeds could be eliminated from American hog-feeding practice the soft-pork problem would largely disappear. On the other hand, the use of the feeds in question is desirable for a number of reasons. The home-grown feeds in this group are well adapted to the soils and climates where they are grown, fit well into crop rotations and farming systems, are soil improvers, have high feeding values when properly used and can be grazed or hogged off, thereby saving harvesting costs. The mill or by-product feeds which must be considered in this connection are easily obtained in the sections where they are most used, are relatively cheap, and possess very satisfactory feeding values when properly supplemented.

The undesirable characteristics of the products from soft hogs, as indicated above, place them at a disadvantage on the market. It is reported that the retailer, in particular, objects to handling them, and, generally speaking, to dispose of them the packer accepts lower prices than for firm products. The packer protects himself by paying accordingly for the live hogs. Thus the producer is compelled to accept, in the usual case, a lower price for soft and oily hogs than he receives for firm hogs. This discrimination in price has varied considerably at different markets and at different times; it is impossible to give an average figure which would be reliable.

The deduction, however, represents a great sum of money when considering the number of soft hogs marketed in the United States during any considerable period of time. It is estimated that the discount on soft hogs passing through one small packing house in a single recent year was more than $100,000, which must be considered as a loss to the producers of that section.

Some sections or localities have become known on the livestock markets as "soft-hog territories," and all hogs received from those sections, regardless of their feeding, are considered by the commission firms and packers as soft until proved to be otherwise.

Most of the packing houses buy these questionable hogs "subject to test," if request for test is made by the producer. Settlement is then made by the packer on the hard-hog price basis if the carcasses chill hard in the cooler. This system seems fair and just on first thought, but considerable dissatisfaction has developed from its actual operation. Country buyers and shippers have claimed the right to sell hogs subject to test and to pocket any margin paid on hard hogs. This, the packers and commission firms assert, is not right. They say that the producer should receive the full benefit

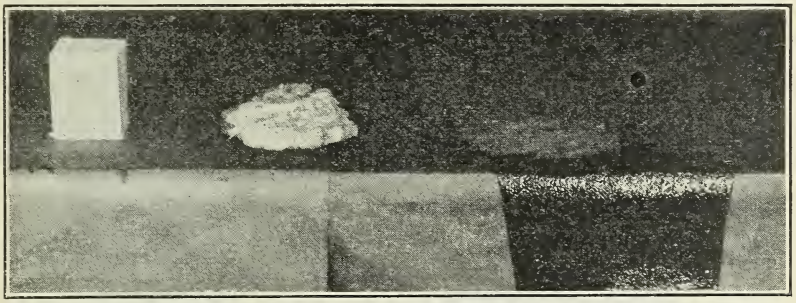

FIG. 3.—Lard from hard, soft, and oily carcasses

of any extra remuneration resulting from the cooler test, and their attitude on this point appears to be unassailable. Then, in many instances there has been criticism of the gradings placed on the carcasses in the coolers. In such cases producers have felt certain that their hogs were firmer than reported, and have been disgruntled because they had no recourse. Whether their complaints were justified it is, of course, impossible to say. Furthermore, it seems hardly fair to the producer in a so-called "soft-hog territory," who raises first-class hogs fed on nonsoftening feeds only, to be compelled to sell subject to test and to accept without recourse the decision of another person as to their firmness. Of course, such a transaction usually is handled with satisfaction to both parties, but cases have occurred in which misrepresentation has been charged. All this makes up one more question which must be considered in connection with the soft-pork problem.

The producer confronts a perplexing situation. It would be good practice to use softening feeds in hog production on many farms if it were not for their influence upon the quality of the product. Do the advantages outweigh the disadvantages? This is one of the unanswered questions. The fact that the feeds are used extensively is evidence of the opinion which many now have on the question.

If their detrimental influence could be overcome, there is no question that their use in hog production would be increased immensely. The producer asks also whether the softness could be avoided and more money made by using other feeds to a considerable extent with the softening feeds, or whether the use of the softening feeds should be discontinued entirely. This would call for replacement by other feeds probably more expensive, which might result in no more, or less, profit. Thus the hog grower in a section of the country well suited to the production of any softening feed or where softening mill feeds are easily obtained and relatively cheap has a difficult problem to solve.

EUROPEAN INVESTIGATIONS

During the last 30 years the subject of the firmness of pork has received the attention of investigators in both Europe and America. Soft pork as an objectionable product has varied a great deal in degree of softness in different countries. In most cases feed has been recognized as the chief cause of variations in firmness.

FIG. 4.—Sausage from oily and hard carcasses

Among the earliest investigations on this subject were those conducted in Denmark by Friis (*5, p. 312; 6, p. 543*)[4] and associates and by Henriques and Hansen (*10*). The former investigators compared various rations in use in Denmark and used a decimal system in grading the chilled carcasses. According to their grading barley, rye, root crops, and palm-nut meal produced firm pork; corn and wheat bran medium pork; and sunflowers soft pork.

Henriques and Hansen, besides confirming these findings on barley and corn, compared the effects of coconut and linseed oils added to barley. They reversed the feeds on the animals several times, removing a piece of fat from the back of the live animal each time for analysis. They were able to trace the relatively soft linseed fat and the hard fat with each change of feed. In addition to studies

[4] Numbers in italic in parentheses refer to "Literature cited," p. 66.

on effect of feed fat, they studied the effect of temperature (*11*) by placing one pig in a warm room, a second, protected by a sheepskin, in a cold room, and a third unprotected in a cold room. They concluded that the low temperature in the third case caused deposition of a softer subcutaneous fat than in other cases. The internal fat did not differ materially.

At the German experiment stations a large number of feeding trials with pigs have been made comparing corn, barley, potatoes (fresh and dried), milk, root crops, and oil-mill feeds, such as palm-kernel meal, coconut meal, sesame cake, peanut meal, soy-bean meal, and linseed meal. In certain cases oils, such as peanut, palm-kernel, and linseed, were added to a basic ration. All the investigators (*3, 15, 16, 17, 19*) were interested in the effect of the feeds, especially the fat of the feed, on the body fat of the pigs. The fat constants, melting point, iodine number, and refractive index were usually determined on samples of fat to show the state of firmness of the hogs. Their findings showed that barley, potatoes, palm-kernel meal, coconut meal, milk, and meat meal in various combinations produced hard fat. Corn produced a slightly softer fat, whereas the feeding of peanut, sesame, and linseed meals or oils resulted in still softer fat. The allowance of these softening feeds in the rations was seldom large enough to give a softness comparable to that found in this country.

Vinson (*24*) and Albert (*1*) concluded that a variation in nutritive ratio (low-protein versus high-protein ration) did not influence the firmness of the fat. The rations they fed were very low in fat and produced hard pork.

König and Schluckebier (*15*) noted the softness of suckling pigs compared with mature pigs fattened on grain, potatoes, and other feeds.

It will be noted that the conclusions of these investigators all point to the important rôle of the food fat. The firmer hogs were produced on feeds low in fat or containing a hard fat, whereas the softer hogs received feeds containing considerable liquid fat.

Jackson (*14*) in a discussion of soft, oily bacon in Great Britain, lays great stress on the effects of rations rich in oil in producing soft bacon. He has attempted to arrange the plant oils and the feeds containing these oils according to their softening power.

CANADIAN INVESTIGATIONS

About 1895 the Canadian bacon industry became alarmed at the large quantity of soft bacon on the market and the great handicap it placed on the profitable production of that commodity. The problem was studied by Day (*4*) and Schutt (*22, 23*) and their work later reviewed by Rommel (*21*). It was found that most of the Canadian soft bacon came from immature or underfed pigs. Usually they had been fed on poorly balanced rations, such as corn alone or beans alone. When rapid, satisfactory growth to maturity was obtained by the use of mixed feeds (corn, barley, peas, skim milk, etc.) the softness was eliminated. In his study Schutt found the softness to be closely associated with the fat; he relied mainly on the melting point and iodine number of the fat to indicate the degree of softness. He considered the amount of "olein" to be the controlling factor in softness. In other words, the quantity of unsaturated fatty acids was closely correlated with the softness of the fat.

AMERICAN INVESTIGATIONS

There is very little information concerning the early history of soft pork in the United States. The principal hog feed of this country has been corn, but for various reasons it has not met with the objections as to softening influence raised in Denmark, Germany, and Canada. There are other crops and their products produced to great advantage and used rather extensively as hog feeds, however, which have become associated, with more or less certainty, with soft pork. For many years the soft-pork problem in the United States was considered as strictly a southern problem on account of the feeds involved, but in recent years, with the more widespread production and feeding of certain crops and mill products, it has outgrown its sectional scope. It must be regarded now as practically nation-wide. As has already been pointed out, a serious economic problem has developed.

Up to 1919 a large amount of work had been done by the southern experiment stations[5] on the softening effects of whole peanuts, peanut meal, soy beans, chufas, mast, rice polish, rice bran, and other feeds, together with a study of the influence of various so-called hardening feeds.

This work involved the use of the feeds mentioned with or without subsequent hardening rations. In some experiments physical grading of the chilled carcasses alone was depended on as the measure of firmness; in others only chemical measures of firmness were used. The proportion of experiments in which both physical and chemical tests were made was comparatively small.

The results of feeding peanuts, either grazed or fed in dry lot, have shown the distinct softening effect. Feeding periods of four weeks or over have usually produced soft or oily hogs.

When one comes to the consideration of hardening peanut-fed pigs the results and opinions of the investigators are very conflicting. The hardening period usually lasted from three to eight weeks, with an average of from five to six weeks. There was apparently little regularity as to the results. Sometimes firm hogs were obtained; sometimes there was little change from the degree of softness at the close of the peanut-feeding period. In spite of this irregularity various workers advised that a finishing period of from four to six weeks could be used profitably to develop at least a moderate degree of firmness in peanut-fed hogs. This very likely helped to create the belief that such hardening periods should produce hard hogs. Throughout all these investigations the fact has been recognized that the peanut is an excellent hog feed when considered in terms of economy of pork production.

As peanut meal began to come on the market it was fed experimentally to hogs at various stations. Being high in protein, it was usually combined with corn in various proportions. Results soon showed that it possessed softening properties, although not so great as whole peanuts. No definite general conclusion could be drawn, however, as to conditions under which peanut meal will or will not soften the pork.

The soy bean received attention second to that given to peanuts. Results appear to have been comparable. The rice by-products

[5] No attempt has been made to discuss American work in detail. The reader is referred to Hare (*8, 9*), and to the list of American experiment station publications following "Literature cited," p. 66.

(rice bran and rice polish) also were fed, with conflicting results. Chufas and mast have been noted as softening feeds.

Although a great deal of valuable information has come out of the results obtained at the American stations, the results were very confusing on some of the most questionable points. This was largely due to the wide range of conditions under which the experiments were conducted.

Since the beginning of the cooperative work, in 1919, several investigators have studied certain phases of the problem independently. Among these are Scott at the Florida station, Hughes at the California station, and Warren and Williams at the Texas station.

Scott, of the Florida station, reported results of experiments in which softening and hardening rations were fed to different lots of hogs and the feeds reversed at the middle point of the experiments. Samples of fat were taken from the live hogs at the beginning of the experiments, when the feeds were changed, and at the close. Melting points, and in one experiment iodine numbers and refractive indexes, of these fats were determined to trace the changes in firmness which occurred with the changes in feed. One of his conclusions was that a hog softened by peanut feeding can be so fed subsequently that the carcass will chill hard.

Hughes (13) reported results of two experiments involving a total of 20 pigs on each feed combination, in which a study was made of the influence of rice and rice by-products on the firmness of hogs. Rough rice, rice bran, and rice polish were each self-fed, free choice, with tankage and with rolled barley and tankage. Rice bran, rice polish, and tankage were self-fed, free choice to another lot. The check lot received rolled barley and tankage, self-fed, free choice. Cooler gradings of the carcasses and chemical tests of the fats were made. He concluded that rice bran was the only feed used which had a softening influence.

Results of two experiments conducted by Warren and Williams, of the Texas station, are worthy of note. Rice polish and rice bran were each fed in varying proportions with corn and tankage. The maximum proportion of both polish and bran fed in the different combinations was 61.2 per cent. One lot was sufficiently soft to be docked in price on the market. It was fed a combination of rice bran, corn chop, and tankage, containing 50 per cent rice bran, for 150 days.

COOPERATIVE PLAN OF THE PRESENT INVESTIGATIONS

The production questions, including the fundamental nature and causes of soft pork, and other questions, such as marketing, shrinkage, and utilization, combine to form what is usually referred to as "the soft-pork problem." Fundamentally, of course, it is a production problem. Other questions are secondary. It has been recognized for many years that the basic questions involved would have to be answered by research agencies, such as the United States Department of Agriculture and the State experiment stations. Much scattered work covering a long period of years had been done along these lines by both American and foreign research institutions prior to the investigations reported in this bulletin. Although some important results had been obtained, it had become evident that complete solution, at least from the point of view of American interests, was far distant under the independent, unorganized method of study.

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The idea was finally conceived of developing a cooperative system of investigation. The principal thought was that only through pooling of the knowledge, financial resources, experimental facilities, and effort in a carefully devised plan of study could the most satisfactory progress be made. Furthermore, results obtained under such a plan of investigation would have the strongest sort of backing and would be reliable. There was no hope of completely solving in a short time a problem on which others had spent years of work. It was realized in undertaking the investigation that it would probably require many years for completion. It was evident that those best situated to cooperate in a comprehensive and long-time investigation were the State experiment stations, meat packers, and the United States Department of Agriculture. Representatives of these three agencies were brought together and the foundation laid for the work, which was begun July 1, 1919.

The first year, as might be expected, required attention to organization and development of a method of study. It was arranged that the cooperating State experiment stations would feed as many hogs as could be handled, with the Bureau of Animal Industry feeding as many as were available at the United States Experiment Farm, Beltsville, Md., and at other Government stations. All major experiments were to be conducted in accordance with detailed plans agreed on by the cooperating stations and the bureau. The new system of study further called for the shipment of all hogs to the United States Experiment Farm at Beltsville, Md., for slaughter. This assured uniform slaughter and chilling conditions for the hogs from all experiments, and was a most decided improvement over the former investigations in which the hogs were handled in various commercial packing plants under widely varying conditions. In many of the former experiments no cooler tests of the carcasses were made.

One of the most important steps taken was the organization of a permanent committee whose function was to be the grading for firmness of the chilled carcasses of all hogs slaughtered in connection with the work. One representative of each of the following was appointed on this committee—the cooperating State experiment stations, the Institute of American Meat Packers, and the Bureau of Animal Industry.[6]

Arrangements were made for chemical tests of fats from each carcass in a Bureau of Animal Industry laboratory at Beltsville, Md.[7] These chemical determinations of firmness were to provide information supplemental to the physical or committee gradings. Thus there would be two measures of firmness of each carcass, the physical and the chemical. It would not be necessary to depend on either one alone, as each would serve as a check on the other.

Method of Procedure

It has been stated that all major experiments are conducted as agreed on by the cooperating stations and the bureau. Shipments of representative animals for slaughter are made to the United States

[6] Earl H. Hostetler, of the North Carolina Agricultural Experiment Station, has represented the State experiment stations, and Howard R. Smith, Baltimore, Md., the Institute of American Meat Packers, on the grading committee continuously from the time of its organization. G. T. Cole, in charge of Federal meat-inspection work at Moultrie, Ga., represented the Bureau of Animal Industry during the first year, and H. K. Walter, who occupies a corresponding position at Washington, D. C., since that time.

[7] During the first year these tests were made in the laboratory of the Meat Inspection Division, Bureau of Animal Industry, Washington, D. C.

Experiment Farm at Beltsville, Md., at specified times. In some cases periodical killings are made during the experiments to trace the changes in firmness which occur as the feeding progresses. It is the usual procedure to kill not less than three representative animals from each experimental lot in each killing. This is done to circumvent, at least partially, the factor of individual variation and to furnish more reliable average figures. Twenty-four hours prior to slaughter the hogs receive their last feed. In other words, the live weight of the animal obtained just before killing is an "empty" or "shrunk" weight.

In the beginning the plan called for a 48-hour chilling of the carcasses before they were graded by the committee. Later it was decided to adopt a 72-hour period when larger numbers of hogs per killing showed a tendency to run the cooler temperature higher during the early part of the chilling period. The temperature is reduced to 38° F. or slightly lower as soon as possible after the warm carcasses are placed in the cooler. A temperature of from 32° to 38° F. is the adopted range of chilling temperatures. The effort is always made to hold the cooler temperature between 34° and 35° F. for the 12 hours or more immediately preceding the grading of the carcasses by the committee.

Seventy-two hours after the hogs are killed the official committee meets to grade the chilled carcasses. The three men work independently (fig. 5). Each man examines each carcass as carefully and as long as necessary to convince himself regarding the degree of firmness. He records his decision on a card which bears hog numbers corresponding to numbers stamped on the carcasses. There are four grades or degrees of firmness (physical) recognized in these investigations. These are "hard," "medium," "soft," and "oily." Carcasses classed as medium are regraded medium hard or medium soft by the committee members, the final grade depending, of course, on the tendency of the medium carcass to be hard or soft. Thus there are actually five grades which are recognized and may be listed as follows: Hard, medium hard, medium soft, soft, and oily.

Figure 6 is a reproduction of a card used by the committee in grading carcasses.

After the independent gradings by the three committee members are completed and the cards signed the average of the three gradings on each hog is determined. This average grading is entered in the records as the official committee grading of the hog.

After the carcasses are graded samples of both back and leaf fat are obtained (fig. 7) for the final chemical determination of firmness. The sample of back fat is taken along the middle of the back between the kidney and the shoulder. Care is observed to obtain a cross section of the fat layer. The leaf fat is taken near the kidney. The fat is immediately placed in glass bottles, rendered in a gas oven at 110° to 115° C., filtered, and kept in a refrigerator except when used for tests.

Early in these investigations the melting point, iodine number, and refractive index determinations were made on both back and leaf fat samples from each carcass. The three tests were continued long enough to determine which was the most reliable. It was found that the melting point was inferior to both the iodine number and

the refractive index. Both the iodine number and the refractive index gave very satisfactory measures of firmness, and the refractive index was adopted as the routine test because of the rapidity with which it could be determined.

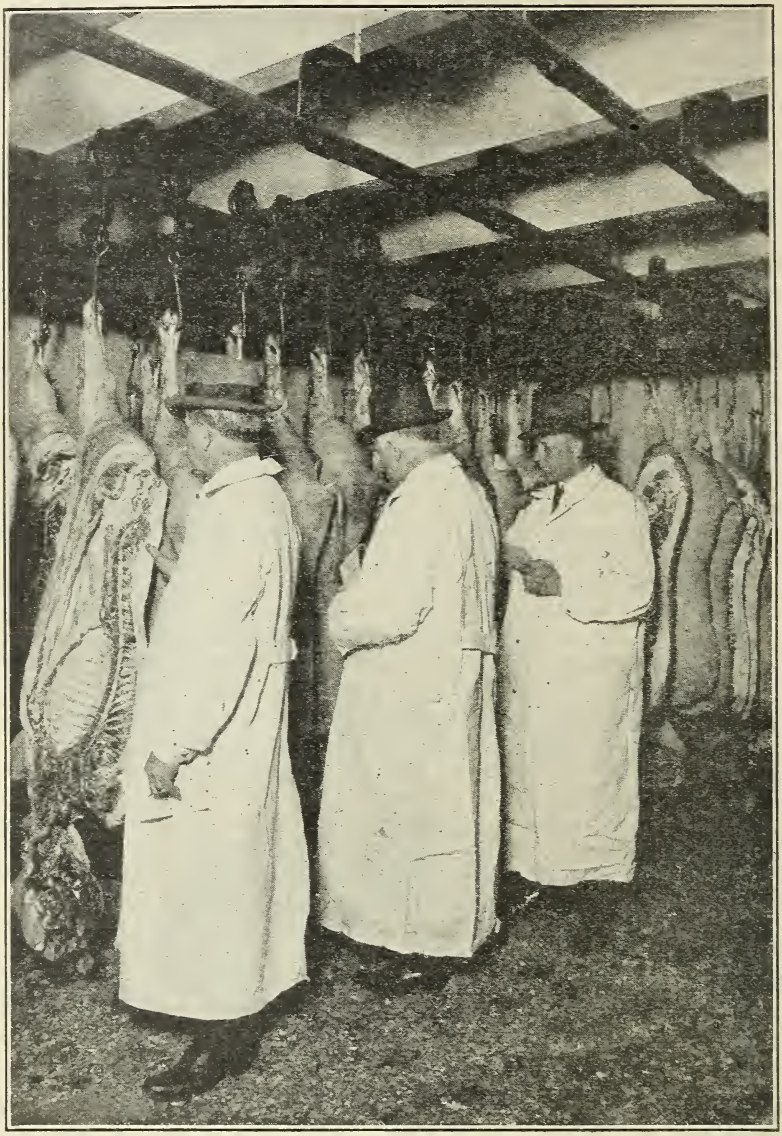

FIG. 5.—Carcass-grading committee at work

Melting point and iodine numbers are no longer determined except in special cases. The sample of back fat has been found to be more representative of the fat in the carcass; hence greater weight is placed on the data from it than from the leaf fat.

Since the refractive index is determined on both preliminary and final samples, a close check on its accuracy and reliability is obtained. However, only the final values are entered in the records.

In order to compare the refractive-index values with the physical grades group limits on back-fat values for the five grades have been designated. Within the limits of each particular grade occurs the maximum number of hogs within that grade. These limits have shifted slightly from year to year, because of unconscious variations in the committee's standards of firmness. About 75 per cent of the hogs handled in the four years' work fall within these grade limits.

Table 1 gives the grade limits which will be used in the interpretation of results presented in this bulletin. It also shows the average of each of the three fat constants for each grade during the time all three determinations were made.

A. H. Form 274

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF ANIMAL INDUSTRY
ANIMAL HUSBANDRY DIVISION

SOFT PORK INVESTIGATIONS
CARCASS GRADING

Hogs from Indiana Station Date 2/16/25

LOT No.	HOG No.	HARD	MEDIUM	SOFT	SOFT AND OILY	REGRADE
1	751	✓				
	752			✓		
	753	✓				
	754	✓				
	755	✓				
	756	✓				
	757	✓				
	758			✓		
2	759	✓				
	761	✓				
	763		✓			soft
	764			✓		
	765		✓			Hard

Signature Howard Smith
Member of committee

FIG. 6.—Form of card used by committee in grading carcasses

TABLE 1.—*Limits of physical grades expressed as refractive index* [1] *and averages of fat constants*

Grade limits of refractive index on back fat (average of four years' results)	Average of fat constants of back fat for all hogs with the indicated grading, 1920–22		
	Refractive index	Iodine number	Melting point
		Per cent	° *C.*
Hard, 1.4597 and below [2]	1.4593	63.0	38.0
Medium, 1.4598 to 1.4605			
Medium hard, 1.4598 to 1.4601	1.4599	68.0	36.5
Medium soft, 1.4602 to 1.4605	1.4603	71.0	35.0
Soft, 1.4606 to 1.4618	1.4611	77.5	31.0
Oily, 1.4619 and above [3]	1.4623	88.0	24.0

[1] The refractive index does not always give an exact measure of the firmness of the hog carcass. In some cases the discrepancy in the refractive index as indicated by the committee grading is due to the nature of the adipose tissue, particularly its thickness and fat content; in other cases it appears to be due to the specific effect on the fat of a certain kind of feeding. However, the refractive index not only gives a check on the gradings but it furnishes a satisfactory means of comparing and showing slight changes in the degree of firmness which are not shown well by the gradings alone. In this bulletin the refractive index is used mainly to show in graphic form the progressive softening or hardening produced by a given ration.

[2] Lowest value recorded, 1.4579.

[3] Highest value recorded, 1.4645.

At the close of each year's work photostat copies are made of the detailed records covering all experiments conducted during the year. Each cooperating institution receives copies of the records of all experiments.

It is part of the plan under which these investigations are conducted to hold a conference each spring of representatives of the institutions engaged in the work. Results of experiments of the preceding year are presented and discussed in detail at this conference. When results justify, conclusions for publication are drafted and approved. With full information regarding previous work and results at hand a program of proposed experiments for the following year is formulated and approved by the conference. This program is followed as closely as conditions permit.

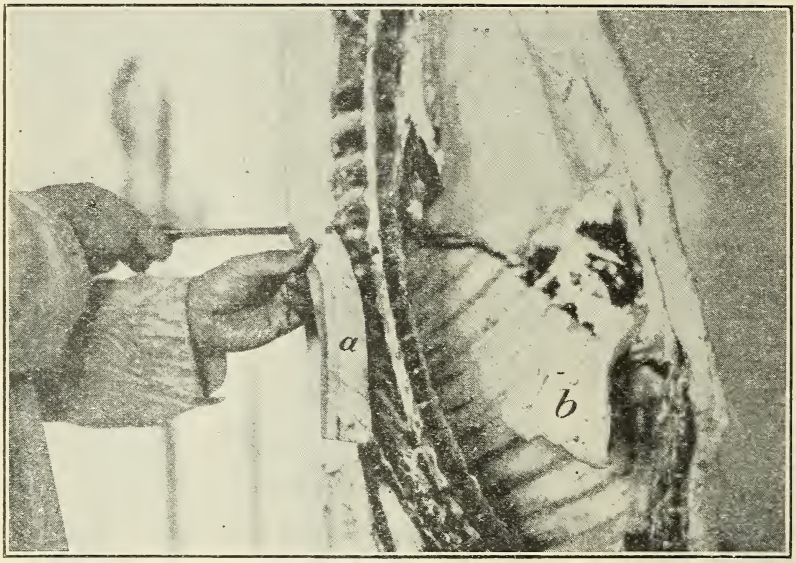

FIG. 7.—Cutting back-fat and leaf-fat samples from hog carcass. (Strip of back fat is shown on the left at *a*, leaf fat on the right at *b*)

BASIC PRINCIPLES OF THE PROBLEM

It has been indicated that the soft-pork problem is very largely a fat problem. It must be understood, in fact, that the firmness of pork depends almost entirely on the firmness of the fat therein. Thus the soft-pork problem is one which demands, to a great extent, the study of body fat and of the constituents which enter into its production.

It is agreed that feed is the outstanding factor among the causes of soft pork. Certain feeds are now recognized as producers of soft pork and others are known to produce firm pork. That feed fat has very important and definite effects on the character of animal body fat has long been known. The feeds under consideration in these investigations vary widely in the quantity and to a certain extent in the character of fat present, but it is characteristic of those recognized as softening that they contain relatively high percentages of fat whereas those known to be hardening are comparatively low in

that constituent. The fat of most of the common feeds, whether present in high or low percentage, is itself soft and in some cases fluid at ordinary temperatures. A wide range of influence on firmness, varying rather closely with the fat present, is exerted by the various common feeds. Hence the primary importance of fat (feed and body) is apparent.

To indicate more clearly the possible variation in effect of the numerous feeds concerned in the soft-pork problem on body fat composition Table 2 is given. It shows the quantity of the fat in each feed in percentage and the quality in terms of iodine number and refractive index. With increase in the two latter values there is associated an increasing softness and degree of unsaturation.

TABLE 2.—*Fat composition of some common feeds*

Feed	Per cent of fat	Iodine number	Refractive index at 40° C.	Feed	Per cent of fat	Iodine number	Refractive index at 40° C.
BASAL FEEDS				SUPPLEMENTAL FEEDS			
Sweet potatoes	0.4						
Brewers' rice	.8	100.0	1.4645	Semisolid buttermilk	3.0 (*12*)	33.0 (*18*)	1.4568 (*18*)
Corn	4.3	126.0	1.4673	Wheat middlings	4.2	115.4 (*18*)	
Oak mast	4.4	100.7		Soy-bean oil meal	6.6	128.0	1.4648
Rice polish	9.7	100.0	1.4645	Cottonseed meal	6.8	107.4	1.4620
Rice bran	14.8	100.0	1.4645	Peanut meal (unshelled nuts)	9.0	93.7	1.4625
Soy beans	17.5 (*12*)	128.0	1.4648	Peanut meal (shelled nuts)	10.8	93.7	1.4625
Chufas (dry)	28.9	76.5	1.4605	Tankage	10.9	[1] 64.5	
Whole peanuts	33.1	93.7	1.4625	Fish meal (menhaden)	11.0	[1] 124.8	
Shelled peanuts	47.6	93.7	1.4625	Soy-bean meal	17.5	128.0	1.4648

[1] Nutrition laboratory, Animal Husbandry Division, cooperating in soft-pork investigations.

With the exceptions noted, the figures given in this table were furnished by the Bureau of Chemistry, United States Department of Agriculture. The refractive index was calculated to the basis of 40° C. from the figures supplied and which were read at 20° C.

It may be assumed that feed fat is usually stored by the hog without material change in character so far as firmness is concerned; also in view of the nature of the common feed fats, that it is usually softening. Such being the case, what is the influence on firmness of the other nutrients, carbohydrates and protein? These nutrients probably take a part in fat deposition only when the supply of fat in the feed is below the demands of body fat and when the supply of carbohydrates and protein is in excess of maintenance requirements. It has been known for many years that body fat can be formed from carbohydrates, and it is generally agreed now that protein may furnish a source of fat when consumed by animals in sufficient quantities. There is no evidence to indicate that firmness is effected by these nutrients in the same way as it is by most of the common feed fats. On the contrary, it appears now that it is normal for carbohydrates and protein to produce hard fat in the animal body. In practical feeding we are more concerned about the influence of the carbohydrates than the protein, since the latter is seldom fed in quantity sufficient to provide any material excess for use in fattening. Common feeds and feed combinations containing high percentages of carbohydrates and low percentages of fat are now recognized as

producers in most cases of hard hogs when the animals are fed to a reasonable degree of finish. The evidence as to the firmness of the fat formed from carbohydrates is so clear and strong that the question seems no longer to be open to argument. The character of fat stored by a hog would seem to depend very largely on the rate of fat deposition in the body in relation to the quantity and character of fat primarily, and of the other nutrients secondarily, in the feed consumed.

Factors aside from feed fat, no doubt, are often partially responsible for softness in hogs, but it is believed that they rank as secondary to fat and usually exert their influence indirectly through their effect on the utilization of the nutrients and the deposition of body fat. Thus, such factors as weight and degree of finish, type, thrift, as measured by rate of growth, diseased conditions, general efficiency and balance of the ration, and possibly environment, can be considered in such a light. By proper regard to their control in connection with feeding they may be treated as minor factors subordinate to the major one, which is feed fat softening in character.

It will be noticed that the percentages of fat in Table 2 vary from less than 1 per cent to 47.6 per cent in the various feeds. This is a very wide range, and it follows that the feeds must vary in their effects on fat formation. The iodine numbers and refractive indexes show considerable variation, but practically all are high, indicating considerable softening power. The former value is the more reliable for comparing oils from different sources. The refractive index is given for purposes of comparison with the value obtained on lards.

The figures given in the table serve to emphasize the value of knowing the relative softening effects of varying quantities of each common feed fat as well as of the same quantity of different fats. However, study of the problem is not a simple matter of conducting comparative feeding trials to cover the points just mentioned. The other nutrients and the so-called secondary factors have an important bearing, under many conditions, on the degree of firmness produced and must be given full consideration.

As will be discussed later, a certain feed or feed combination may be softening under certain conditions and hardening under others. This pertains particularly to those feeds with moderate quantities of softening fat. Those containing much softening fat will produce their effects regardless of moderate variations in other factors. On the other hand, with feeds extremely low in softening fat or containing hard fat (characteristic of very few common feeds) the primary tendency, of course, is for the hog to store a hard fat regardless of other conditions.

During the normal growth of a pig the adipose tissue is constantly being built up. The hardening of an animal already made soft, therefore, would seem to be accomplished by the addition of enough hard fat to the previous store of soft fat to cause the mixture to be satisfactorily firm. This is more difficult than it appears at first. Corn, our principal hog feed, fed with a protein supplement throughout the growing and fattening periods, produces at desirable market weight and finish only the standard or required degree of firmness. When this is realized it is easy to see the difficulties involved in attempting to harden a well-grown soft or oily pig in the short time usually demanded in economical feeding practice. If the previous

softening can not be avoided (a questionable point with feeds like peanuts), then the finishing ration ought to have very pronounced hardening qualities to be really effective. It should be kept in mind, however, that any feeds suggested for use, in addition to other qualities, must be sufficiently plentiful and cheap to permit profitable feeding.

The importance of using in this work large numbers of animals of proper breeding, feeding, and management, with the fullest possible history of feeds, weights, etc., has been fully realized. Every effort has been made to obtain these essentials.

RESULTS OF THESE INVESTIGATIONS

In most of the experiments reported in this bulletin an effort was made to start the pigs at a weight of approximately 100 pounds. In some tests the pigs were purposely started at other weights; in other cases it was impossible to have them at the desired weight at the beginning. Initial weight will be referred to specifically under each of the following sections reporting conclusive results. To avoid, so far as possible, the use of unthrifty pigs a standard was adopted early in these investigations which called for an age of not more than from 6 to 7 months at the 100-pound weight. This might have been more strict, but some latitude was necessary on account of the difficulties involved in obtaining suitable animals.

Purebred pigs of the Berkshire, Chester-White, Duroc-Jersey, Hampshire, Poland-China, and Tamworth breeds were used, as well as a number of pigs of grade, crossbred, and mixed or unknown breeding. Approximately equal numbers of barrows and sows were used. With a few exceptions the pigs in these experiments were of medium type. Care was exercised in all experiments to have the lots as nearly uniform as possible in all respects, except when the different lots were purposely started at different average weights.

A. CORN WITH TANKAGE, FISH MEAL, AND WHEAT MIDDLINGS

Nature of the Feeds

Corn is the most important grain crop and hog feed produced in the United States. It has a very wide adaptation and is available for feeding purposes in practically all sections of the country where hogs are grown. Table 3 gives the composition of dent corn and of the supplemental feeds which are to be considered here.

Table 3.—*Composition of corn, tankage, fish meal, and wheat middlings*[1]

Feed	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Dent corn	12.9	1.3	9.3	1.9	70.3	4.3
Tankage	7.6	22.2	53.7	1.8	3.8	10.9
Fish meal	6.8	20.5	58.3	.7	2.7	11.0
Wheat middlings	10.1	3.5	16.3	4.3	61.6	4.2

[1] Figures from Bureau of Chemistry, U. S. Department of Agriculture.

The carbohydrate content of corn is very high and the fat content is not low when compared with many other common feeds. The

carbohydrates occur mainly as starch. The fat of corn is composed largely of the unsaturated or fluid fats (see Table 2), which exert a softening influence on the body fat of hogs. Corn is low in crude protein, which is not of the best growth-producing quality. The ash or mineral matter content likewise is low. Thus in corn we have a feed which is strictly fattening in character. The best practice in hog feeding calls for some kind of protein supplement to corn for all classes of hogs.

Corn is commonly considered as the standard hardening feed for hogs which have previously received softening feeds. As a matter of fact, hogs which have been fed mainly corn without any softening supplementary feeds throughout their lives to a finished weight and condition are considered on the markets as possessing, with few exceptions, the standard degree of firmness. Although corn fat itself is softening, as mentioned above, its influence is usually obscured in corn feeding because of the low percentage present as compared with other nutrients, particularly carbohydrates.

Tankage is a packing-house by-product highly valued in hog feeding for its protein and mineral-matter content. The composition of tankage makes it a valuable supplement to corn. It is probably the commercial protein concentrate most widely used in hog feeding. The combination of corn and tankage, used in different proportions, is practically a standard in many sections for both growing and fattening hogs.

Fish meal is a by-product in the manufacture of fish oil. It is only in recent years that its high value as a protein concentrate for hogs has been demonstrated in the United States. There is but little difference in the composition of fish meal and tankage, and as hog feeds they may be considered as practically interchangeable.

Wheat middlings are used extensively in hog feeding as a supplement to corn, with or without additional supplements. The protein content is moderately high, and it is for that reason primarily that the feed is so widely used. The carbohydrate content, however, is also rather high, and the fat percentage is about the same as corn. The quality of the fat likewise is practically the same (see Table 2) as corn fat.

Methods of Feeding

A large number of hogs have been fed corn with the above-mentioned supplements during both growing and fattening periods in connection with these investigations. The rations used in this work were (1) corn with tankage or fish meal, and (2) corn and middlings with tankage or fish meal. In some cases pasture has been available for the animals. This is likewise true of mineral-mixture supplements. In a few experiments corn and tankage mixed in definite proportions have been hand-fed. In all others the feeds have been supplied in separate compartments of self-feeders. None of the hogs were fed any softening feeds prior to receiving the feeds mentioned.

Weights of Pigs Used

The summary of the results on firmness of the carcasses covers a total of 371 hogs, and the participating institutions were the Alabama, Arkansas, Indiana, Kentucky, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas experiment sta-

tions, the Coastal Plain Experiment Station, McNeill, Miss., the Iberia Livestock Experiment Farm, Jeanerette, La., and the United States Experiment Farm, Beltsville, Md. Ninety of the 371 animals were so-called "check" pigs, which were slaughtered at weights ranging from about 50 to 150 pounds. They were killed at the beginning of the experiments as representative of the firmness of the pigs used in the tests, and had been grown on the respective rations mentioned above. The remainder were fed in experimental check or control lots on the respective rations mentioned. The slaughter weights of all hogs ranged from 34 to 316 pounds.

Variation in Firmness of Carcasses

The hogs have been divided according to final weights into subgroups, the weight interval for each being 25 pounds. The hogs in the first subgroup weighed from 25 to 49 pounds "off test,"

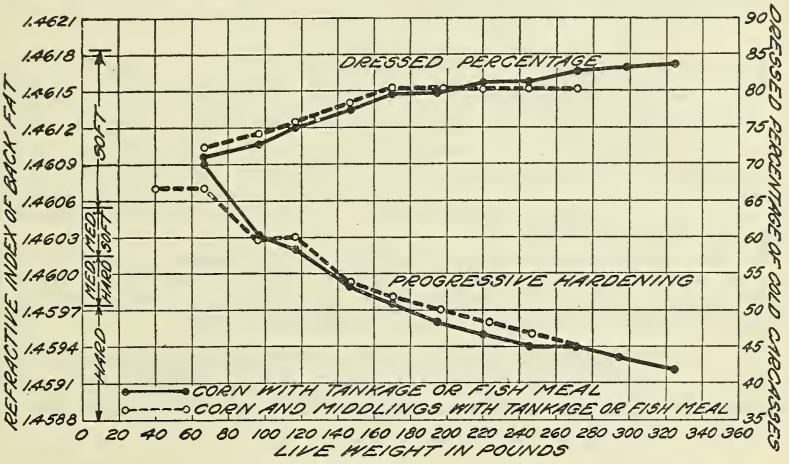

FIG. 8.—Curves showing progressive hardening of hogs fed on corn with nonsoftening protein supplements. The dressed percentage which indicates the finish of the animal is also shown

those in the second from 50 to 74 pounds, and so on. This has been done to bring out more clearly the relation between weight, finish, and firmness. The averages of the final weights, dressed percentages, committee gradings, and refractive indexes of back fat for each of the two groups—(1) corn with tankage or fish meal, and (2) corn and middlings with tankage or fish meal—were calculated and are shown in Figure 8.

The refractive index of the back fat and the committee grading are plotted against the weight in the lower part of the figure, and the dressed percentage, representing the degree of finish, is plotted against weight in the upper part. The curves for the hardness of the two groups are practically identical. The middlings group is usually the softer when there is a difference.

The outstanding and important fact is the progressive hardening of the pigs as they take on weight and finish. Young, weanling pigs are soft (sometimes very soft), with an average refractive index of 1.4607 on the corn and middlings with tankage ration and 1.4609

on the corn and tankage ration. One-hundred-pound pigs, the weight at which a large number of the experiments have been started, are medium soft with a refractive index of 1.4603.

The dividing line between medium soft and medium hard is at about 130 pounds, and that between medium hard and hard at about 170 pounds. Above the latter weight the hogs continue to become harder, so that at 320 pounds the refractive index is 1.4592 as compared with 1.4608 (the average of both groups at 67 pounds). Since the dressed percentage increased as the weight and degree of hardness increased, the influence of maturity is thus emphasized. The relation of age has not been included in this discussion, because of its apparent minor importance as compared with weight and finish. It was observed in preparing this chart, however, that there were a number of hogs, particularly among the subgroups from 100 pounds to 200 pounds, much above the average age which were slightly softer than the majority. Because of their slow rate of gain they had probably utilized their feed differently, resulting in the deposition of the softer fat.

In view of the important facts brought out by the results from the rations under discussion, the following conclusions were included in a statement [9] issued by the cooperating agencies in July, 1924:

(*a*) There is a direct relation between immaturity and softness in pigs. When pigs are fed on ordinary feed combinations which are not unusually low in fat content, such as corn and tankage, or corn, middlings, and tankage on pasture or in dry lot, and slaughtered at a weight of approximately 100 pounds or less, they are, in the usual case, soft.

(*b*) Hogs fed corn and tankage gradually become firmer as they mature or take on weight and finish. While hogs fed in this way are usually soft at 100 pounds or less, the hardening is progressive, so that when slaughtered at approximately 175 pounds or more they are, in the usual case, hard.

As a supplement it may be added to the second statement that a ration of corn, middlings, and tankage has a similar effect. It is understood that fish meal may replace tankage in either of the combinations without changing the result.

Progressive Hardening of Hogs Fed Corn and Tankage

Some closely controlled work has been done at the United States Experiment Farm, Beltsville, Md., supplemental to these cooperative studies to determine the reason for the progressive hardening of hogs fed corn and tankage. Three litters, numbering 19 pigs, were used. The sows were fed nonsoftening feeds during the gestation period and a mixture of corn meal 8 parts, wheat middlings 4 parts, and fish meal 1 part, on rye pasture during the suckling period. Two litters had access to a mixture of corn meal 100 parts and tankage 15 parts on pasture beginning at about 4 weeks of age and continuing throughout their lives. The third litter was handled in a similar manner on a ration of corn meal 100 parts, tankage 14.5 parts, and alfalfa meal 6 parts on pasture. Feed consumption records were kept and representative pigs killed at six stages of growth and fattening for physical and chemical study.

The real explanation for the gradual increase in degree of firmness was thought to lie in the widening ratio of the quantity of feed fat consumed to the quantity of body fat stored. Thus primary at-

[9] The statement referred to was composed of 10 conclusions. They will be restated at appropriate points in this bulletin.

tention was given to the determination of these quantities as well as to the quality of the fats for each animal slaughtered. The results obtained are shown in Figure 9.

The weight of body fat shows the usual rapid rise expected in the fattening period. Of course this is only a confirmation of a fact known for many years, that the rate of fat increase in a "fattening" hog is much higher than in a "growing" pig.

The weight of feed fat consumed from the time of weaning was actually determined by ascertaining the percentage of fat in the feed and applying it to the quantity of feed consumed. Since this did not include the fat consumed in the sow's milk and in the grain eaten during the suckling period, an estimated quantity of 4.5 pounds was added to the known amount. Therefore the curve for weight of feed fat consumed from birth more nearly represents the true figures. Probably well over 90 per cent of the feed fat was absorbed by the animals.

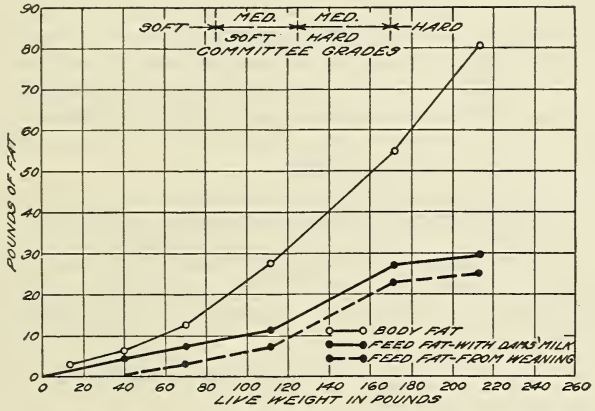

FIG. 9.—Quantitative relations of the ingested fat to the body fat

The widening ratio of feed to body fat is best illustrated by comparing the proportions at various live weights. Thus at 80 pounds live weight there had been 8 pounds of feed fat consumed to 16 pounds of body fat stored, whereas at 160 pounds the ratio was 24 pounds of feed fat to 50 pounds of body fat. Finally, at 215 pounds live weight there had been consumed 29.5 pounds of feed fat to 80.5 pounds of body fat stored. Approximately the change in ratio was from 1:2 to 1:3. A similar experiment, preceding this one, in which the feed combination was 1 part corn meal and 3 parts skim milk, gave essentially the same results.

The feed fat absorbed was probably used mainly for deposition in the adipose tissue. This fat, derived largely from corn, being of a softening nature, would form a soft fat in the tissue. The fat synthesized from carbohydrates and protein has been found to be much firmer. Thus as larger and larger proportions of carbohydrates and protein enter into fat formation in the animal (with a corresponding decrease in the proportion of feed fat) the total adipose tissue would gradually become firmer through the mixing of the firmer fat with the softer.

Feeding Results with Corn and Tankage[10]

Complete feeding records are not available for all the 371 hogs which were included in the preceding summary on firmness. However, summaries have been made of the feeding results from as many as possible of the hogs fed corn with tankage or fish meal. These summaries cover check or control lots of hogs fed as stated in connection with these investigations. The lots were fed at the Alabama, Indiana, North Carolina, Oklahoma, South Carolina, and Texas experiment stations, the United States Experiment Farm, Beltsville, Md., and the Coastal Plain Experiment Station, McNeill, Miss. Fourteen experiments involving 325 hogs are included in the following tables and discussion. The experiments are divided into three groups, for the purpose of reporting feeding results, as follows:

Corn and tankage mixed, hand-fed.
Corn and tankage self-fed, free choice.
Corn and fish meal self-fed, free choice.

In most of the experiments an effort was made to start the pigs at 100 pounds weight. This was not true in all cases, however, and for that and other reasons there was considerable variation in initial weights. On account of this variation and the difference in methods of feeding, the results reported in the following tables are not for comparison. The feeding results from each of the three groups should be considered independently.

The feeding results from hogs hand fed mixtures of corn and tankage in dry lot for fattening purposes are shown in Table 4.

Table 4.—*Corn and tankage mixed, hand-fed, in dry lot*

Number of pigs used		75
Average number of days fed		82.92
Average initial weight	pounds	82.36
Average final weight	do	149.23
Average gain	do	66.87
Average daily gain	do	.81
Average feed consumed per 100 pounds gain:		
Corn	do	451.57
Tankage	do	49.75
Mineral mixture (based on results from 40 hogs)	do	5.65
Total feed	do	506.97

Calculation from this table gives the average proportion of corn to tankage consumed as 9.1 : 1. Only 40 of the 75 hogs had access to minerals. The data from which the table was prepared do not indicate that the other 35 hogs were at a disadvantage so far as rate and economy of gain were concerned.

Table 5 gives feeding results of more than 200 hogs self-fed corn and tankage, free choice, in dry lot during the fattening period.

Table 5.—*Corn and tankage self-fed, free choice, in dry lot*

Number of pigs used		202
Average number of days fed		60.08
Average initial weight	pounds	106.55
Average final weight	do	201.89
Average gain	do	95.34
Average daily gain	do	1.59
Average feed consumed per 100 pounds gain:		
Corn	do	383.94
Tankage	do	34.32
Mineral mixture (based on results from 55 hogs)	do	5.46
Total	do	423.72

[10] Fish meal instead of tankage was fed in one Beltsville experiment, and it is discussed separately.

Approximately 7 per cent less total feed was consumed per 100 pounds gain by the 55 hogs which had access to mineral mixture than by the other 147 hogs.

One experiment was conducted at the United States Experiment Farm, Beltsville, Md., in 1923–24, in which corn, fish meal, and mineral mixture were self-fed, free choice, in dry lot to pigs starting at an average weight of approximately 33 pounds. Table 6 summarizes the feeding results of this experiment.

TABLE 6.—*Corn, fish meal, and mineral mixture self-fed, free choice, in dry lot*

Number of pigs used		48
Average number of days fed		136. 13
Average initial weight	pounds	33. 42
Average final weight	do	165. 06
Average gain	do	131. 64
Average daily gain	do	. 97
Average feed consumed per 100 pounds gain:		
Corn	do	346. 90
Fish meal	do	31. 10
Mineral mixture	do	5. 00
Total feed	do	383. 00

In this case it is noticeable that through a feeding period of practically 136 days the feed, including mineral mixture, required to produce 100 pounds gain was only 383 pounds.

B. PEANUTS

NATURE OF THE FEED

The peanut is outstanding among the feeds recognized as producers of soft pork. It is used extensively in some sections of the country as a feed for hogs. There is no feed commonly used in hog production which has a higher oil or fat content. Table 7 shows the composition of peanuts.

TABLE 7.—*Composition of the peanut* [1]

Kind of peanut	Water	Ash	Protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
With shell	6. 0	2. 8	24. 7	18. 0	15. 4	33. 1
Kernel without shell (as consumed by hogs)	5. 5	2. 3	30. 2	2. 8	11. 6	47. 6

[1] Figures from Bureau of Chemistry, U. S. Department of Agriculture.

In addition to the fact that the peanut has a high fat content, the fat is composed very largely of the unsaturated fats (see Table 2), which are fluid at ordinary temperatures and softening in their influence on the body fat when consumed by hogs. The peanut is considered as a fattening feed and is commonly fed alone as such, giving very satisfactory results from the feeding standpoint. Its composition suggests, however, that it may be suitable also as a feed without supplement for growing pigs, although this question has never been settled.

WEIGHTS OF PIGS USED

In most of the peanut-feeding experiments the pigs have been started at an average weight of approximately 100 pounds. Lighter-weight pigs have been used purposely in some experiments, however,

and for that and unavoidable reasons the initial weights have varied considerably. The extremes of the range in beginning weights of the 252 peanut-fed pigs on which complete carcass and fat test data are available were 47 pounds and 190 pounds.

Softness of Carcasses of Peanut-Fed Hogs

A great deal of study has been devoted to the influence of peanuts alone or with mineral supplement on the firmness of carcasses. Late in the spring of 1922 the following statement was issued by the cooperating agencies:

> Cooperative soft-pork experiments conducted by the United States Department of Agriculture and the State experiment stations of Georgia, Mississippi, North Carolina, and South Carolina during the last three years have shown conclusively that when pigs starting at a weight of approximately 100 pounds are fed on peanuts in the dry lot or grazed in the field for a period of 60 days or more a soft (includes both soft and oily) carcass is produced.

Complete data are now available from 252 hogs fed peanuts alone and slaughtered without subsequent feeding. Work has been done at the Alabama, Oklahoma, and Texas stations in addition to those named in the statement above. Some of the hogs have grazed peanuts in the field, others have been self-fed unshelled peanuts in dry lot, and still others have been self-fed shelled peanuts in dry lot. The data furnished by these hogs and their carcasses have been studied from various angles, according to initial weights, gains, committee gradings, refractive indexes, and methods of feeding peanuts to bring out the essential facts. The results leading up to the above-stated conclusion and to other facts are presented in the pages immediately following.

To point out first the decided softening influence of peanuts, as shown by the condition of the carcasses in the cooler, Table 8 is given. This table shows the grades into which the 252 carcasses were placed by the committee and the number and percentage in each grade.

Table 8.—*Distribution of carcasses of 252 peanut-fed hogs, by grades, showing the number and per cent in each grade*

Grade	Number of carcasses	Per cent of carcasses
Oily	142	56.3
Soft	97	38.5
Medium soft	12	4.8
Medium hard	[1] 1	.4
Hard	0	.0
Total	252	100.0

[1] The committee grading of this carcass may be questioned on account of the refractive index, which was 1.4607. This carcass will be considered as "soft" in the following discussion.

The influence of peanuts on firmness is shown clearly by Table 8. A total of 239, or 94.8 per cent, of the carcasses were either soft or oily. The 12 hogs, representing 4.8 per cent, of medium-soft carcasses would have been considered on the market as soft and will be treated here as such. This leaves 1 hog out of the 252 which was graded as medium hard but chemically was soft and is thus open to question.

Table 9 summarizes the data from these hogs, giving averages of initial weights, gains, days fed, rates of gain, weights at slaughter, and refractive indexes of back and leaf fats. In the first section of the table all hogs are considered together; in the second section oily and soft [11] hogs are compared, and in the third the self-fed hogs are compared with those grazed on peanuts, with subgroups of oily and soft under each.

TABLE 9.—*Averages of weights, gains, feeding periods, and refractive indexes of back and leaf fats of 252 hogs fed peanuts alone or with mineral supplement*

Number of hogs	Grading	Initial weight	Gain	Days fed	Daily gain	Weight at slaughter	Refractive index	
							Back fat	Leaf fat
	ALL HOGS	*Pounds*	*Pounds*		*Pounds*	*Pounds*		
252	Oily and soft	104.21	68.52	59.38	1.15	166.93	1.4619	1.4613
	OILY VERSUS SOFT							
142	Oily	101.08	76.44	65.64	1.16	171.39	1.4623	1.4616
110	Soft	108.25	58.30	51.30	1.14	161.17	1.4615	1.4609
	SELF-FED IN DRY LOT VERSUS GRAZED							
	Self-fed							
94	Oily	100.40	83.63	72.19	1.16	177.13	1.4623	1.4616
60	Soft	106.52	63.10	51.37	1.23	162.75	1.4614	1.4609
	Oily and soft	102.79	75.63	64.08	1.18	171.53	1.4619	1.4613
	Grazed							
48	Oily	102.40	62.35	52.81	1.18	160.17	1.4623	1.4616
50	Soft	110.34	52.54	51.22	1.03	159.28	1.4616	1.4610
	Oily and soft	106.45	57.35	52.00	1.10	159.71	1.4619	1.4613

In considering the 252 hogs as one group in Table 9, it should be noted that the initial weight was 104.21 pounds and the gain 68.52 pounds, produced during a feeding period of 59.38 days. More than half of the carcasses were oily and the remainder soft. The refractive index of back fat (1.4619) shows them to average oily. (See Table 1.) Thus the truth of the conclusion that pigs starting at a weight of approximately 100 pounds and fed on peanuts in dry lot or grazed in the field for a period of 60 days or more produce soft or oily carcasses is clearly shown. The difference of 5.8 pounds between the initial weight plus gain and the weight at slaughter was a shrinkage due to the fact that the hogs received their last feed 24 hours prior to slaughter.

The second section of the table which compares oily and soft hogs shows that, with little difference in initial weights, the gains were 76.44 pounds and 58.30 pounds, respectively, or a difference of 18.14 pounds. The refractive indexes of back fat were 1.4623 and 1.4615, agreeing very satisfactorily with the physical gradings. It is evident that as the gain on peanuts increased the degree of softness increased.

In the third section of the table, which compares the hogs self-fed with those grazed on peanuts, it should be noted that the former,

[11] The soft classes in the table include the 12 medium soft and 1 medium hard as indicated previously.

totaling 154, gained 75.63 pounds, whereas the latter, totaling 98, gained 57.35 pounds. The refractive index of back fat of each group was 1.4619. It is of particular interest that, although the hogs grazed on peanuts made 18.28 pounds less gain than those self-fed, with a difference of only 3.66 pounds in initial weights, the average degree of softness, according to the refractive index, was the same in both groups. Comparing the oily self-fed and oily grazed hogs, it is seen that the latter with 21.28 pounds less gain acquired the same degree of softness as the former. The soft self-fed hogs, although making 10.56 pounds more gain than the soft-grazed hogs, were slightly firmer than the latter (1.4614 as against 1.4616). Most striking of all is the comparison of soft self-fed and oily grazed hogs. With weights, gains, and other factors practically the same, the grazed hogs showed the oily condition with a refractive index of back fat 9 points higher (1.4623 as against 1.4614) than the self-fed hogs which were graded as soft by the committee. Thus it appears that hogs grazed on peanuts develop a higher degree of softness than hogs self-fed peanuts in dry lot when weights, gains, and other factors are equal.

Relation of Initial Weight and Gain to Softening Effects of Peanuts

As has been stated, most of the pigs fed on peanuts were started on experiment at approximately 100 pounds. There has been a wide range in individual starting weights, however, ranging from 47 pounds to 190 pounds. Most of the hogs with the extreme weights, both low and high, were killed at the close of the peanut-feeding period in experiments designed mainly to determine the influence of variation in initial weight on the requirements for hardening. In addition to this variation in initial weights, the gain on peanuts has varied from 10 to 190 pounds. This difference was due to two factors, the time on experiment and the rate of gain.

The influence of the two variables—the initial weight and the gain—on the degree of softness is shown in Table 10 and in Figure 10. As indicated in the table, the 252 hogs were divided into three groups according to initial weights. The group limits were: (1) Under 85 pounds; (2) 85 to 114 pounds; and (3) over 114 pounds. These limits give a fairly good proportion of hogs to each group and give average weights in round numbers of 70, 100, and 133 pounds, respectively.

TABLE 10.—*Relation of the initial weight and gain in weight of hogs to softening effects of peanuts*

GROUP I. INITIAL WEIGHT UNDER 85 POUNDS

Gain interval, pounds	Number of hogs	Initial weight	Gain	Days fed	Average daily gain	Grade distribution [1]	Refractive index	
							Back fat	Leaf fat
		Pounds	*Pounds*		*Pounds*			
0 to 24	4	66	18	29	0.62	4S	1.4616	1.4613
25 to 49	12	65	37	52	.71	9S, 3O	1.4619	1.4616
50 to 74	18	71	61	57	1.07	3S, 15O	1.4622	1.4618
75 to 99	9	78	84	60	1.41	4S, 5O	1.4622	1.4616
100 to 124	3	75	119	88	1.36	3O	1.4627	1.4623
125 to 149	2	55	137	277	.50	2O	1.4629	1.4624
150 to 174	2	57	171	196	.87	2O	1.4629	1.4623
175 to 199	1	72	188	114	1.65	1O	1.4630	1.4630
Weighted average (total)	51	69.2	69.2	71	.97	20S, 31O	1.4621	1.4617

GROUP II. INITIAL WEIGHT 85 TO 114 POUNDS

0 to 24	4	96	21	35	0.58	1S, 3O	1.4613	1.4608
25 to 49	23	99	39	53	.73	15S, 8O	1.4618	1.4612
50 to 74	58	100	63	59	1.07	19S, 39O	1.4621	1.4614
75 to 99	26	101	86	61	1.41	5S, 21O	1.4622	1.4615
100 to 124	8	108	106	61	1.75	3S, 5O	1.4622	1.4614
125 to 149	1	102	142	89	1.60	1O	1.4625	1.4619
150 to 174	1	102	158	117	1.36	1O	1.4627	1.4618
175 to 199	1	85	190	117	1.65	1O	1.4631	1.4629
Weighted average (total)	122	100.2	67.4	58.9	1.14	43S, 79O	1.4621	1.4614

GROUP III. INITIAL WEIGHT OVER 114 POUNDS

0 to 24	5	132	18	28	0.66	1MH, 4S	1.4607	1.4599
25 to 49	14	135	37	41	.90	9S, 5O	1.4614	1.4609
50 to 74	26	136	64	55	1.16	19S, 7O	1.4614	1.4608
75 to 99	20	131	85	58	1.48	5S, 15O	1.4618	1.4611
100 to 124	12	129	108	59	1.85	4S, 8O	1.4620	1.4613
125 to 149	2	134	130	58	2.25	2S	1.4618	1.4612
Weighted average (total)	79	133	69.7	52.1	1.34	1MH, 43S, 35O	1.4616	1.4610

[1] The initial letters in this column, O, oily; S, soft; and MH, medium hard.

The subgroups were arranged according to gains in 25-pound intervals, which is sufficiently large to give marked differences in most cases in the refractive indexes. Although the number of hogs in certain of the subgroups of high peanut gain is low (one to three hogs), all the results are in harmony with one another.

The more important aspects of the results are best shown in Figure 10. The weights of the pigs (initial weight plus the gain) are plotted against the refractive indexes of the back fat. The corresponding committee grades are also shown with the latter. The base curve shows the progress of hardening on corn and nonsoftening supplements as discussed in a previous section. The starting points of the three group curves on the base curve represent the degree of

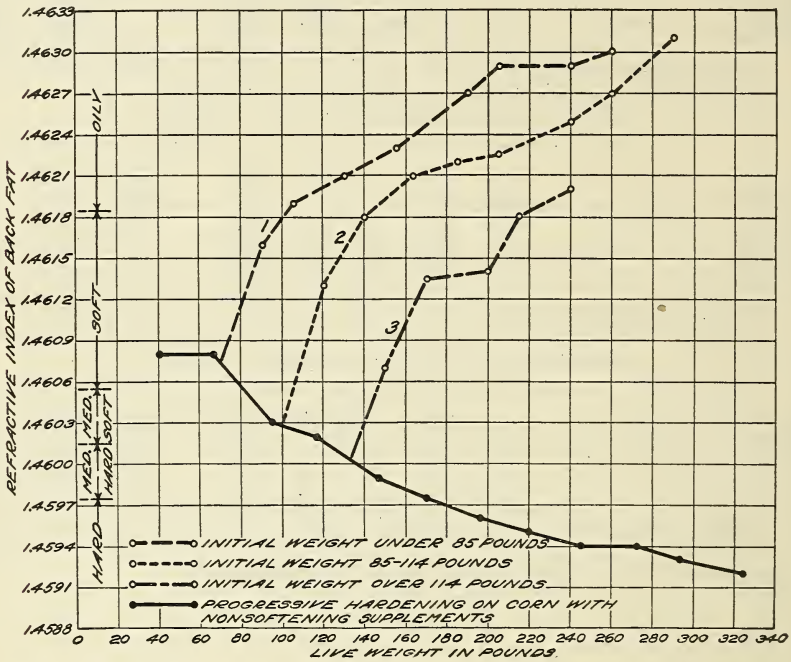

FIG. 10.—Curves showing relation of initial weight and gain to softening effects of peanuts. The base curve in this and subsequent figures represents the progressive hardening on corn with nonsoftening protein supplements

softness at the time the pigs were placed on experiment. The chart shows that there was a progressive softening with an increasing gain in weight, rapid at first but decreasing after about 40 pounds of gain on peanuts had been made.

The three groups show practically the same changes in the rate of softening. There are certain abnormalities at points along the curves which would probably be corrected if more hogs were available to be included in the averages, particularly in Groups 1 and 3. Allowing for these irregularities, the three groups follow the same general course in softening. There is a difference in the degree of softness for equal gains, the order for decreasing softness being 1, 2, and 3. Apparently this difference is due chiefly to a similar variation at the starting weights. The maximum softness in Group

1 is 1.4630 in a hog making 188 pounds of gain; in Group 2 it is 1.4631 for a similar gain, which is shown in Table 10 only. This is probably near the maximum degree of softness attainable on peanuts. The average refractive index of peanut oil (see Table 2, whole peanuts) is 1.4625. Thus, higher values have been obtained on samples of back fat than the average of peanut oil, which, however, may be as high as 1.4645.

It is of interest to observe in this figure that (1) the gain required to reach the oily stage is 34, 42, and 90 pounds in the order of increasing initial weight, and (2) the degree of softness attained with 60 pounds of gain (an amount usually made in approximately an eight-weeks' feeding period) is 1.4622, 1.4620, and 1.4614 in the same order. The narrow range between Groups 1 and 2 in both cases would probably be widened if the abnormalities in the curve were corrected as previously suggested.

Feeding Results with Peanuts

Three methods of feeding peanuts, as explained previously, have been used in these investigations. They are as follows:

(1) Peanuts grazed in the field.
(2) Unshelled peanuts self-fed in dry lot.
(3) Shelled peanuts self-fed in dry lot.

In some experiments mineral mixtures have been self-fed as supplementary to the peanuts.

It is fully recognized that under practical farm conditions peanuts are usually grazed off by the hogs. There are circumstances, however, under which harvested peanuts, shelled and unshelled, are fed to hogs. In these experiments, with few exceptions, the peanuts have been self-fed only when conditions made it impossible to do grazing.

Peanut-grazing work furnishing the feeding results given below was done in connection with these investigations at the Mississippi, North Carolina, South Carolina, and Texas stations. Eight experiments were conducted throughout a four-year period, from 1919 to 1922, inclusive. The Spanish variety of peanuts was used in all cases. The results are summarized in Table 11.

Table 11.—*Summary results of feeding peanuts grazed*

Number of pigs used		146
Average number of days fed		47.09
Average initial weight	pounds	107.13
Average final weight	do	161.68
Average gain	do	54.55
Average daily gain	do	1.16
Total peanut acreage grazed	acres	52.51
Estimated yield per acre [1]	bushels	17.98
Average gain produced per acre	pounds	151.67

[1] Yield estimates available on only 41.05 acres of the 52.51 acres grazed.

It should be noted that the average daily gain through a grazing period of 47.09 days was 1.16 pounds. Another point worthy of particular notice is the large number of hogs represented. Considering the number of animals involved and their satisfactory average quality, together with the conditions under which the experiments were conducted, it is believed that the average daily gain of 1.16 pounds is a dependable figure. It seems that pigs of average quality starting on peanuts in the field at approximately 100 pounds' weight may be expected to gain at about the rate mentioned for a period of from seven to eight weeks under ordinary farm conditions.

The average estimated yield per acre (17.98 bushels) is based upon estimated yields at the Mississippi station in 1919 and 1922, at the South Carolina station in 1921, and at the Texas station in 1921 and 1922. At none of these stations is the soil well adapted to the production of peanuts, although it may be in other parts of those States. In fact the only station able to utilize good peanut soil was that of North Carolina at its Edgecombe substation, where an experiment was conducted in 1921. In consequence of the low yields of peanuts the quantity of gain per acre is low. Good peanut land in a normal year should produce double or probably more than double the gain per acre reported in Table 11.

The following results of feeding unshelled peanuts in dry lot were obtained from 14 experiments conducted at the Alabama, Georgia, North Carolina, Oklahoma, South Carolina, and Texas stations, the Coastal Plain Experiment Station, McNeill, Miss., and at the United States Experiment Farm, Beltsville, Md. The work covered a four-year period from 1921 to 1924, inclusive. Table 12 gives a summary of the results.

TABLE 12.—*Summary of results of feeding unshelled peanuts self-fed in dry lot*

Number of pigs used		316
Average number of days fed		60.07
Average initial weight	pounds	96.64
Average final weight	do	166.53
Average gain	do	69.89
Average daily gain	do	1.16
Feed consumed per 100 pounds gain:		
Unshelled peanuts	do	351.90
Mineral mixture (based on results from 133 hogs)	do	9.40
Total	do	361.30

Table 12 shows that the 316 pigs made an average daily gain of 1.16 pounds. This figure, it should be observed, is identical with the corresponding figure in Table 11.

C. CORN WITH NONSOFTENING PROTEIN SUPPLEMENTS FOLLOWING PEANUTS

The hardening of hogs which have become soft or oily by the exclusive feeding of peanuts is a problem of great practical importance. It is only natural that corn, because of its outstanding importance in hog production and its influence on firmness, should be considered as the standard feed for hardening soft hogs. Much study had been given prior to these cooperative investigations to the hardening quality of corn for hogs previously fed on softening feeds, especially peanuts. There were many conflicting opinions, however, as to the time required to harden peanut-fed hogs with a ration of corn and tankage or a similar supplement.

In the investigations herein reported experiments have been conducted at the Georgia, Mississippi, North Carolina, and South Carolina stations and at the United States Experiment Farm, Beltsville, Md., to determine (1) whether it is possible to harden such hogs on corn and supplement, and if so, (2) the time and gain necessary. The hardening period of the experiments usually followed an 8-week period on peanuts. In most instances the experiments reported in this section (C) were a continuation of those included in section B on peanut feeding. In the early experiments the hardening period had a duration of 8 weeks, half of the hogs being killed at the end

of 4 weeks and the remainder at the close. When it was found that 8 weeks were insufficient to produce hogs of satisfactory firmness, the time was increased to 12 weeks with killings at 4-week intervals. Finally the time was extended to 24 weeks, the 4 and 8 week killings were omitted, and provision thus made for four killings at the 12, 16, 20, and 24 week stages.

The Hardening Rations Used

Corn and a nonsoftening protein supplement were fed throughout the hardening period of all experiments reported here. The supplements used with corn were tankage, fish meal, wheat middlings, semisolid buttermilk, and cottonseed meal. When the semisolid buttermilk was used as the supplement each pound was diluted with 3 pounds of water and then 3 pounds of the liquid (after dilution) fed per pound of corn meal. The cottonseed meal was always alternated with tankage in four-week feeding intervals and comprised one-third of a mixture with corn meal. Each of the other supplements mentioned was self-fed, free choice, with corn. Wheat middlings, semisolid buttermilk, and cottonseed meal were fed to a relatively small number of hogs. No appreciable difference in firmness could be detected under the conditions of the experiments, and for that reason the results have been included with the others in which tankage and fish meal were fed.

Nature of the Feed

The nature of corn, tankage, fish meal, and wheat middlings has been discussed under section A. Table 13 gives the composition of semisolid buttermilk and cottonseed meal.

Table 13.—*Composition of semisolid buttermilk and cottonseed meal*

Feed	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Semisolid buttermilk (*12*)	65.0	2.7	13.4		15.9	3.0
Cottonseed meal, prime [1]	6.9	5.9	38.8	12.2	29.4	6.8

[1] From Bureau of Chemistry, U. S. Department of Agriculture.

Semisolid buttermilk, a commercial product, is raw buttermilk condensed under reduced pressure to a fraction of its original volume. Before feeding it is diluted to approximately its original state. It is assumed that the feeding value is neither increased nor reduced by the processing to which it is subjected. As stated above, in feeding in connection with these investigations each pound of semisolid buttermilk was diluted with 3 pounds of water. Thus, after dilution the fat content was 0.75 per cent. The quality of the fat is shown in Table 2.

Cottonseed meal is one of the few vegetable feeds which furnish protein in high percentage. It would seem to be a valuable feed for hogs were it not for its poisonous effect on this class of animals when used beyond a certain point. Allowing for its limitations, cottonseed meal has been used with satisfactory results as a supplement

to corn in hog feeding. The fat content is almost double that of corn and middlings, but cottonseed meal is not considered a softening feed. The quality of the fat is indicated in Table 2.

Weights of Pigs Used

Only those experiments are considered in this section of the bulletin in which the average weight of the pigs at the beginning of the peanut feeding was from 85 to 114 pounds, inclusive. Some data have been obtained relative to the hardening influence of corn and tankage upon pigs started on peanuts at less than 85 pounds as well as above 114 pounds and so fed for eight weeks or more, but those data are too insufficient to be conclusive and must be supplemented before publication.

Hardening Effects of Corn and Nonsoftening Supplements

The results on 97 hogs have been summarized for the present discussion. The hogs included had initial weights on peanuts of from 85 to 114 pounds, inclusive. They made gains on peanuts ranging from 25 to 94 pounds, and gains on corn and supplement of from 29 to 246 pounds. The averages of the results are shown in the first part of Table 14. This table also gives the average of the results on 20 hogs of the 97 which were graded hard or medium hard.

Table 14.—*Hardening of peanut-fed hogs with corn and nonsoftening supplements. Initial weight on peanuts, 85 to 114 pounds*

Number of hogs	Initial weight	Gain		Days on feed		Slaughter weight	Average grade	Refractive index	
		Peanuts	Corn	Peanuts	Corn			Back fat	Leaf fat
AVERAGES OF ALL HOGS									
	Pounds	*Pounds*	*Pounds*			*Pounds*			
97	98.45	59.06	114.2	54.6	88.1	280.1	Soft	1.4605	1.4600
AVERAGE OF HOGS GRADED HARD OR MEDIUM HARD									
20	97.3	56.10	182.6	56.4	130.1	320.1	Medium hard.	1.4600	1.4595

The results given in this table show the 97 hogs to have made a gain on corn with supplements practically double that made previously on peanuts. The gradings on these hogs ranged from oily to hard, with an average grade of soft. The average refractive index of the back fats was 1.4605, indicating the softness to be near the upper limit of the medium-soft line.

The gain on hardening feed necessary to obtain medium-hard hogs (the average of the 20 given in Table 14) was 182.6 pounds, made in 130.1 days. This was more than three times the peanut gain. The average refractive index of the back fat was 1.4600, which is within the limits of the medium-hard grade. Because of the practical aspects of these results, statements of conclusions were issued in the spring of 1922 and again in 1923. The 1923 statement, which includes the essential part of that of 1922, follows:

Three years of continued investigation of the soft-pork problem by the North Carolina, Georgia, Mississippi, and South Carolina experiment stations in cooperation with the United States Department of Agriculture showed that when hogs started at a weight of approximately 100 pounds were fed on peanuts for a period of 60 days a soft carcass was produced, and that it was impossible to produce a hard carcass by feeding corn and tankage or corn and cottonseed meal to these soft hogs for a subsequent period of 60 days.

Since the four years' work has been summarized the results show that 100-pound pigs softened on peanuts during a period of 60 days are made firmer by subsequent feeding of hardening feed. However, it is yet impossible from these data to recommend a practical method of producing a strictly hard carcass from such hogs.

From the facts brought out in the summary of the data on the group of 97 hogs the basis for the foregoing statement is apparent. In the statement, for the sake of convenience, the time in each feeding period was given as 60 days. The actual figures on the 97 hogs are even more striking. With the time on peanuts as 54.6 days, a hardening period of 88.1 days was not sufficient to produce hard carcasses. That the hogs are made firmer is apparent when the refractive index of peanut-fed hogs (see Table 9) is compared with the figure of 1.4605 on the 97 hogs summarized here. The long time and the excessive gains required to produce medium-hard hogs make evident the fact that it is as yet impossible from these data to recommend a practical method of producing a strictly hard carcass from such hogs.

RELATION OF GAINS TO FIRMNESS

The observation was made early in the work that for normal, thrifty pigs the weight at which the pig was placed on peanuts, the gain made on this feed and the gain subsequently made on hardening feed were closely related to the firmness of the carcass. In order to show this in graphic form (fig. 11) another summary has been made on the 97 hogs shown in Table 14.

In the present discussion no attempt is made to interpret the factor of starting weight. This interpretation can be made only when sufficient reliable results are available on lighter and heavier pigs than the 85 to 114 pound group considered here. The effect of the relative gains has been the primary object in mind. Of course, when the normal average daily gain of hogs on the different feed combinations is known the approximate time to produce any gain can easily be estimated. In this way the results can be interpreted on a time basis as well as on gains.

The hogs were divided into groups according to the quantity of gain on peanuts, as follows: Group I, 25 to 49 pounds; Group II, 50 to 74 pounds; and Group III, 75 to 99 pounds. The hogs were then subgrouped in 25-pound intervals according to gain on corn and supplement. Thus a hog weighing 105 pounds at the start, making a gain of 65 pounds on peanuts and 115 pounds on corn and supplement, would be placed in Group II, and in the subgroup under this having the range 100 to 124 pounds. The weights, gains, committee grades, refractive indexes, etc., for each hog were tabulated and averages made for each subgroup. The curves in Figure 11 for the progressive hardening on corn and nonsoftening supplement and for the softening on peanuts for 100-pound pigs are the same as shown in Figure 10. Knowing the average gain on peanuts in the three groups, corresponding points on the curve for softening on peanuts

were taken as starting points for the three curves for hardening on corn. The live weights at the close of experiment were used in all cases. The hardening effect of the corn and supplement following the peanuts is apparent. The failure to reach the same degree of firmness as developed in hogs fed exclusively on corn and nonsoftening supplement is likewise apparent.

With the increase in the gain on peanuts there is a correspondingly higher degree of softness at any weight or gain on the hardening feed, although for equal gains this difference lessens as the gain increases.

For equal gains on the two feeds the rise and lowering of softness are far from equal. As an illustration, the pigs making 63 pounds of peanut gain show a rise of refractive index from 1.4603 to 1.4621, a difference of 18 points, whereas for a like gain on corn and supple-

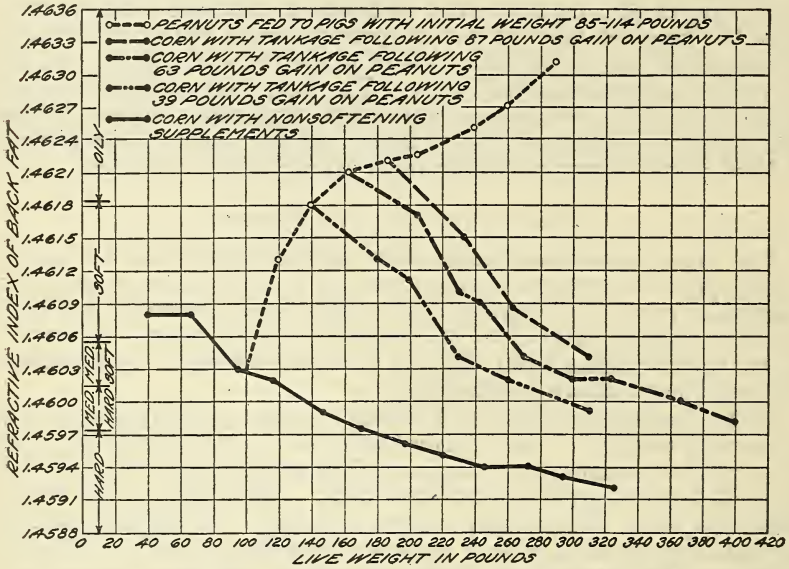

FIG. 11.—Results of feeding corn with nonsoftening protein supplements after the feeding of peanuts. The initial weights ranged from 85 to 114 pounds and the average gains on peanuts of the three groups fed the hardening ration were 39, 63, and 87 pounds

ment the drop of refractive index was from 1.4621 to 1.4613, or 8 points. The point of 1.4603 was not reached until the hog weighed 285 pounds, a gain of 122 pounds on the hardening feed, and even then was medium soft. From this point the rate of hardening was very slow. With a gain on corn and supplement of 189 pounds (final weight 352 pounds), which is three times the peanut gain, a medium-hard carcass has been obtained.

From the standpoint of time the 63 pounds gain on peanuts may be taken as the average of an eight-week feeding period, allowing for an average daily gain of approximately 1.15 pounds. In the hardening period the usual gain in an eight-week period is about 78 pounds, using an average daily gain of 1.4 pounds. This would produce a hog having a live weight of 241 pounds. The refractive index at such a weight is 1.4609, which indicates a strictly soft hog.

Feeding Results with Corn and Tankage Following Peanuts

The experiments which furnish the feeding results given below were conducted at the Georgia, Mississippi, North Carolina, and South Carolina stations, and at the United States Experiment Farm, Beltsville, Md. Nine experiments, covering a period of five years, 1919 to 1923, inclusive, are included in the report. As stated previously in this section under the discussion of firmness, only those experiments are considered here in which the weight of the pigs at the beginning of the peanut feeding was from 85 to 114 pounds, inclusive.

The peanuts used in these experiments were fed in two ways, as follows: (1) Peanuts grazed in the field, and (2) unshelled peanuts self-fed in dry lot. Supplementary mineral mixtures were self-fed in some cases.

The peanut-feeding period in all experiments considered, with one exception, at the Mississippi station in 1921, was approximately eight weeks. The hogs in that experiment grazed peanuts only 42 days, but made unusually good gains. On the basis of gain, which is the more important consideration, they are comparable with the other hogs fed peanuts somewhat longer.

The corn and tankage [12] were self-fed, free choice, in dry lot in all cases, and in several experiments a mineral mixture supplement was likewise self-fed. The duration of the corn and tankage hardening periods varied considerably in the different tests, ranging from 4 to 24 weeks. The fact is fully recognized that some of these hardening periods were carried far beyond the practical point. It has seemed necessary from the scientific standpoint, however, to determine how much time and gain on corn and tankage are required to produce firm hogs when they have been fed previously on peanuts under the conditions explained.

Table 15.—*Results of feeding corn and tankage self-fed, free choice, in dry lot following peanuts grazed and self-fed*

PEANUT-FEEDING PERIOD		
Number of pigs used		157
Average number of days fed		54.45
Average initial weight	pounds	101.85
Average final weight	do	159.18
Average gain	do	57.33
Average daily gain	do	1.05
CORN-AND-TANKAGE-FEEDING PERIOD		
Number of pigs used		115
Average number of days fed		84.36
Average initial weight	pounds	160.29
Average final weight	do	268.36
Average gain	do	108.07
Average daily gain	do	1.28
Feed consumed per 100 pounds gain:		
Corn	do	467.82
Tankage [1]	do	27.60
Mineral mixture (based on results from 45 hogs)	do	6.66
Total feed	do	502.08

[1] Fish meal instead of tankage was used in the 1922–23 experiment conducted at the North Carolina station.

Table 15 gives a summary of the feeding results obtained during the hardening periods of these experiments. Essential data pertaining to the preliminary or peanut-feeding period are also shown.

[12] Fish meal instead of tankage was used in the test conducted at the North Carolina station in 1922–23. It is considered on a par with tankage in feeding value and influence on firmness when fed as a supplement to corn.

Table 15 shows that 157 pigs were used throughout the peanut-feeding period. A total of 42 were slaughtered at the close of that period, however, leaving 115 which were subsequently fed the hardening feed. This explains the difference in numbers. By referring to the peanut-feeding results reported under section B it will be observed that they are closely comparable with the data pertaining to peanut feeding given in the first part of Table 15.

D. SOY BEANS

The soy bean must be given serious consideration in any thorough study of the soft-pork problem. Its use as a concentrated feed in hog production in the United States has increased at an astonishing rate during recent years. The soy bean has a wide adaptation and is grown in practically all sections of the country. It is cultivated and used extensively as a hog feed in those sections which produce hogs in greatest numbers. It is probable that this feed is of greatest importance among those recognized as softening in the United States.

Nature of the Feed

As shown by Table 16, the fat and protein content are high. By referring to Table 2 it will be observed that, except peanuts, the fat percentage is the highest of the more common hog feeds; also that the fat is decidedly softening in character. Because of its high-protein content the soy bean is adapted to use as a supplement to corn in hog feeding. It is used to some extent as a basal feed, however, in localities where corn is scarce and relatively high in price. Under such conditions soy beans are usually hogged off after the seeds have begun to ripen, either without supplement or, more often perhaps, with a limited supplementary ration of corn. The studies reported here have been with soy beans alone (this section) and with a supplementary ration of 2 to 2.5 per cent corn (section F), both rations with or without minerals.

Table 16.—*Composition of the soy bean (12)*

	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Soy-bean seed	9.9	5.3	36.5	4.3	26.5	17.5

Initial Weights of Pigs Used

The standard, calling for initial weights of approximately 100 pounds, was followed in connection with most of the experiments in which soy beans were grazed or self-fed alone or with mineral-mixture supplements. To avoid some variation was impossible. The range of initial weights of the 40 hogs fed as stated and on which complete feeding, carcass, and fat-test data are available was 48 to 163 pounds. The average initial weight was 95 pounds.

Softness of Carcasses of Soy-bean-fed Hogs

The work on the influence of soy beans alone (grazed and self-fed) and with mineral supplement on the firmness of carcasses was conducted at the Mississippi and North Carolina stations and the United States Experiment Farm at Beltsville, Md. Thirty-nine of the forty hogs were graded oily, soft, or medium soft. One was classed as medium hard by the grading committee, but chemically was medium soft and thus is open to question. Furthermore, this animal had the highest initial weight (163 pounds) of the 40 pigs and made a small gain (23 pounds) on soy beans. There is no question, therefore, regarding the softening influence of this feed.

Table 17 summarizes the data from these hogs, giving averages of initial weights, gains, days fed, rates of gain, weights at slaughter, committee gradings, and refractive indexes of back and leaf fats.

Table 17.—*Averages of weights, gains, feeding periods, gradings, and refractive indexes of back and leaf fats of 40 hogs fed soy beans alone (grazed and self-fed) and with mineral supplements*

Number of hogs	Grading (average and distribution) [1]	Initial weight	Gain	Days fed	Daily gain	Weight at slaughter	Refractive index	
							Back fat	Leaf fat
ALL HOGS		*Pounds*	*Pounds*		*Pounds*	*Pounds*		
40	S—{11O, 23S, 5MS, 1MH}	95.00	43.43	52.33	0.83	132.03	1.4623	1.4617
GAIN OVER AVERAGE								
22	S—{7O, 14S, 1MS}	99.55	62.05	52.59	1.18	153.82	1.4628	1.4622
GAIN UNDER AVERAGE								
18	S—{4O, 9S, 4MS, 1MH}	89.44	20.67	52.00	.40	105.39	1.4615	1.4611

[1] The initial letters in this column, O, oily; S, soft; MS, medium soft; and MH, medium hard.

In the table the averages of the data on all 40 hogs are given first. It should be noted that the average committee grading was "soft" and the refractive index of back fat 1.4623. Below the averages on the 40 hogs two groupings are given which divide the hogs according to the gain made. The 22 which gained more than 43.43 pounds (the average) on soy beans are shown in one group, and the 18 which gained less than the average in the other. Comparing the two groups it will be observed that with an initial weight of only 10 pounds more, but having made 41.38 pounds greater gain, the 22 hogs had an average refractive index of back fat 13 points higher than the other group, showing the former to be distinctly softer. Thus the reasons are brought out for another of the conclusions which were issued in July of 1924. The conclusion follows:

Soy beans grazed or self-fed alone or with minerals self-fed through a period of from seven to eight weeks to pigs starting at approximately 100 pounds initial weight and making gains of from 40 to 50 pounds produce soft carcasses. Furthermore, the results have shown that the degree of softness of the carcass increases as the gain in weight of a hog on this feed increases.

RELATION OF INITIAL WEIGHT AND GAIN TO SOFTENING EFFECTS OF SOY BEANS

In order to determine whether the initial weight and the gain had an influence on the degree of softness produced by soy beans similar to that observed in the peanut feeding, the data on the 40 hogs shown in Table 17 have been studied in a similar manner. They were first grouped according to initial weights and then subgrouped according to gains. The averages of the initial weights, gains, refractive indexes, and committee gradings are shown graphically in Figure 12.

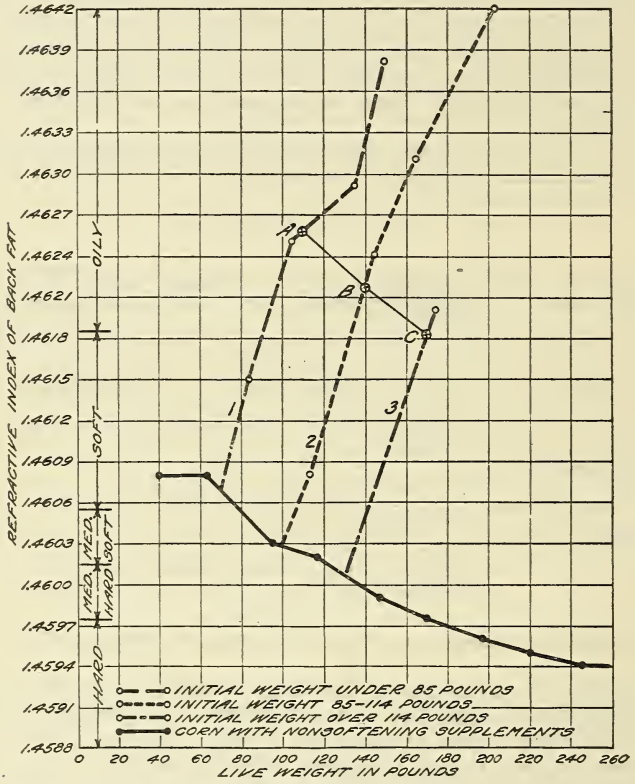

FIG. 12.—Relation of initial weight and gain to subsequent effects of soy beans. The average weights of the three groups fed soy beans were 70, 100, and 130 pounds

Curves 1, 2, and 3 show the rate of softening for average initial weights of 70, 100, and 130 pounds, respectively. Compared with peanuts the rate and the degree of softness developed, according to the refractive index, appear to be much greater. The refractive index of soy-bean oil is about 1.4670 to 1.4680, and the maximum obtained on the hog fat was 1.4642. The latter was probably not the highest point attainable, since the curves show no signs of flattening off to a constant, as occurred with peanut-fed hogs at about 1.4631, which is approximately the refractive index of peanut oil.

The question of interest in this connection is whether the degree of oiliness in the carcasses of these soy-bean-fed hogs was greater

than in the case of peanut-fed hogs from the standpoint of committee grading. Apparently there was not an observable difference, even between values of 1.4640 in the former compared with 1.4630 in the latter. This condition is probably explained by the fact that the soy-bean-fed hogs handled thus far were not so fat as those fed peanuts; hence the influence of the pure fat on the oiliness of the chilled carcass was not so noticeable. In addition, the extreme degree of oiliness in both cases makes differences less noticeable than in firmer hogs.

Oily hogs were produced with less gain in the 70-pound pigs than in the 100 or 130-pound pigs. The gain required for each weight was somewhat less than that required in peanut feeding, especially in the case of the 130-pound pigs. The relation of the initial weight and gain to the degree of softness is best illustrated by points A, B, and C in the chart. They show that there is a decrease in the degree of softness as the initial weight increases when the gains are equal. This is apparent from the direction of the line connecting the three points.

Feeding Results with Soy Beans Fed Without Grain Supplement

The fact that soy beans ordinarily are fed to hogs as a supplement to or supplemented by other feed is fully appreciated. In these investigations it has been considered necessary, however, to determine, largely as a basis for further work, the influence of soy beans on firmness when fed without supplemental grain feed. Certain feeding results have been obtained in connection with that study.

Two methods of feeding soy beans were used in these investigations, as follows: (1) Mature soy beans grazed in the field, and (2) threshed soy beans self-fed in dry lot.

A mineral-mixture supplement was self-fed in one grazing and in one dry-lot experiment. The grazing experiments were started when the bean pods were beginning to turn brown. Very few pigs were self-fed soy beans, and for that reason those feeding results will not be reported here.

Eight experiments, covering a period of four years, 1920 to 1923, inclusive, were conducted at the Mississippi and North Carolina stations and at the United States Experiment Farm at Beltsville, Md. A total of 118 pigs were used in the eight grazing experiments. The Mammoth Yellow variety of soy beans was used at the Mississippi and North Carolina stations and the Virginia variety at the United States Experiment Farm.

The effort was made in most of the experiments to start the pigs at 100 pounds' weight, but the variation in average initial weights of the animals used in the eight experiments was from 72 to 144 pounds. The average initial weight of the 118 pigs was 103.56 pounds. Table 18 summarizes these experiments.

Table 18.—*Averages of initial and final weights, total and daily gains, and days fed of hogs grazed on soy beans without grain supplement*

Number of pigs used		118
Average number of days fed		54.16
Average initial weight	pounds	103.56
Average final weight	do	137.15
Average gain	do	33.59
Average daily gain	do	0.62

The average daily gain in these experiments was 0.62 of a pound. There was a wide variation, however, in the rate of gain—from 0.17 of a pound per hog per day in one Beltsville experiment to 1.21 pounds in one experiment at the Mississippi station. In fact, the gains were consistently more rapid in the four experiments conducted at the Mississippi station than in the one North Carolina and the three Beltsville tests. The mineral-mixture supplement self-fed to 10 hogs in one test at the Beltsville farm resulted in more rapid gains. The average daily gain in that experiment was 0.85 of a pound with mineral supplement and 0.30 of a pound without.

Incomplete data make it inadvisable to discuss the economy of production uuder this system of feeding. The reader is referred to Mississippi Circular 49 (*2*) for a full report of the feeding of soy beans at that station.

E. CORN WITH TANKAGE FOLLOWING SOY BEANS

Explanation was made under section C of the reason for the rather extensive feeding of corn and tankage subsequently to the various softening feeds in these investigations. A determination of the exact influence of such a feed combination on the softness of hogs previously fed soy beans has been considered a problem demanding early study. The work along this line has been conducted at the Mississippi station and at the United States Experiment Farm, Beltsville, Md. Results are still incomplete, but the data on hogs started on soy beans between the weights of 85 and 114 pounds show a distinct hardening effect from corn with tankage following soy beans. Figure 13 shows the results obtained to date. Twenty-six hogs, averaging 100 pounds at the start, made 29 pounds gain on soy beans and 97 pounds gain on the hardening ration. The average grade of the carcasses of these hogs bordered between a medium soft and a medium hard. The average refractive index was 1.4600. In order to compare gains more directly results on 14 of these hogs were averaged. They gained 44 pounds on soy beans, which is the same as the average gain of the 40 hogs discussed in the preceding section. The gain on corn and tankage amounted to 86 pounds, or double that on the soy beans. The refractive index was 1.4605, with the majority of the grades running soft to medium soft.

By reference to Figure 13 the facts brought out in the conclusion below become apparent. The conclusion is from the July, 1924, release. The moderate rate of gain on soy beans referred to may be taken as the 44 pounds on the 14 hogs. This is approximately an average gain of 0.8 of a pound per day for eight weeks. A subsequent gain in weight on corn and tankage equal to that previously made on the soy beans (point A) shows the hogs to be still soft. In the cooperative experiments which have been conducted the hogs which made moderate gains on soy beans usually made excellent gains on corn and tankage, so that the total gain on the latter ration was twice that on the former, such being the case of the 14 hogs shown in the chart. Incidentally, the 14 hogs had feeding periods of equal length and were moderately soft at slaughter.

Soy beans grazed or self-fed alone or with minerals self-fed to pigs starting at approximately 100 pounds weight and making at least a moderate rate of gain through a period of from seven to eight weeks will not produce firm carcasses, even though a subsequent gain in weight has been made by the pigs on corn and tankage equal to that previously made on the soy beans.

Feeding Results with Corn and Tankage Following Soy Beans

The feeding results from four experiments, one conducted at the Mississippi station and the others at the United States Experiment Farm, are combined in Table 19 and the discussion. The experiments covered a period of three years, 1921 to 1923, inclusive. Each of the four experiments was a continuation, through the hardening period, of an experiment included in the summary under the preceding section (D) of this bulletin. Only those tests are considered here in which the average initial weight of the pigs at the beginning of the soy-bean-feeding period was between 85 and 115 pounds, inclusive.

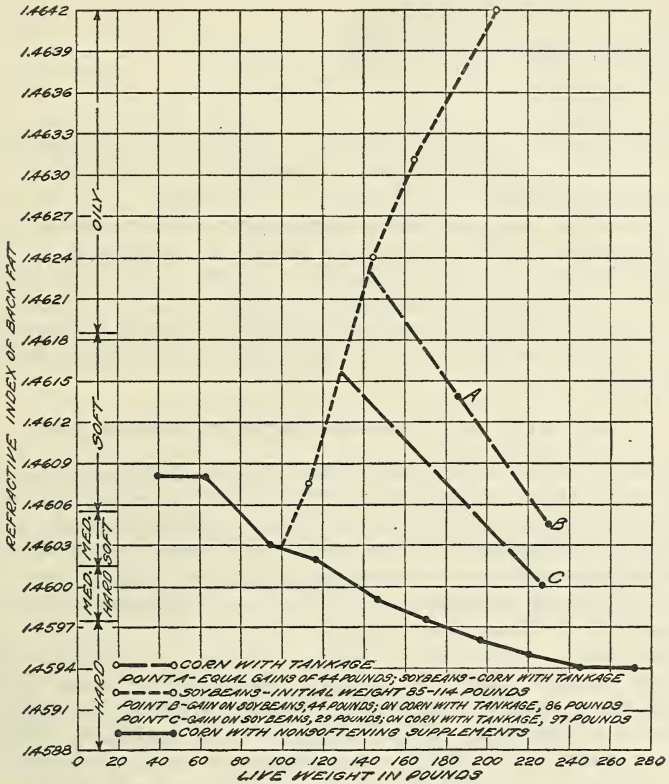

Fig. 13.—Results of feeding corn and tankage after the feeding of soy beans to hogs having initial weights ranging from 85 to 114 pounds

In all four experiments the soy beans were grazed, the pigs being turned into the fields after the seed had begun to mature. One-half, or 10, of the pigs in the 1923 experiment at the Beltsville farm had access to mineral mixture in a self-feeder while grazing the beans. In all other cases the pigs had soy beans without supplement. Mineral mixture was self-fed, free choice, with corn and tankage during the hardening period of all experiments with the exception of the Mississippi test.

Table 19 summarizes the feeding results obtained during the hardening periods of the four experiments. Essential data pertaining to the preliminary or soy-bean-grazing period are also shown.

TABLE 19.—*Corn and tankage self-fed, free choice, following soy beans grazed*

SOY-BEAN-GRAZING PERIOD		
Number of pigs used		66
Average number of days fed		50.26
Average initial weight	pounds	105.12
Average final weight	do	130.38
Average gain	do	25.26
Average daily gain	do	.50
CORN-AND-TANKAGE-FEEDING PERIOD		
Number of pigs used		48
Average number of days fed		52.00
Average initial weight	pounds	130.17
Average final weight	do	223.58
Average gain	do	93.41
Average daily gain	do	1.80
Feed consumed per 100 pounds gain:		
Corn	do	381.96
Tankage	do	24.75
Mineral mixture (based on results from 42 hogs)	do	6.76
Total feed	do	413.47

Table 19 shows that 66 pigs were used in the four experiments through the soy-bean-grazing period. Eighteen were slaughtered at the close of that period, however, leaving 48 which received the hardening feeds following soy beans. The results given in the first part of the table compare satisfactorily with those reported in Table 18 under section D. The 48 hogs made an average daily gain of 1.8 pounds, which is a very satisfactory figure. The feed consumed per 100 pounds gain in the Mississippi test, in which no mineral supplement was fed with the corn and tankage, was not enough greater than the general average (413.47 pounds) to be worthy of separate consideration.

F. SOY BEANS PLUS A MEDIUM RATION OF SHELLED CORN

Conditions under which the farmer finds it desirable to feed a limited corn ration to pigs grazing soy beans frequently arise. It has been considered important, therefore, in these investigations to determine the influence on firmness of soy beans grazed or self-fed when supplemented with a medium ration of shelled corn. From 2 to 2.5 pounds of shelled corn per day per 100 pounds live weight were hand-fed in these experiments.

The Kentucky, Mississippi, North Carolina, and South Carolina experiment stations and the United States Experiment Farm at Beltsville, Md., made this study. Twelve experiments were conducted over a four-year period, 1920 to 1923, inclusive. With the exception of two tests which were conducted at the Beltsville farm, the beans were hogged down, the pigs being turned into the fields after the seed had begun to ripen. In the two Beltsville tests mentioned threshed soy beans were self-fed in dry lot. The Virginia variety was used in all Beltsville experiments, the Mammoth Yellow at the Mississippi and North Carolina stations, the Mammoth Yellow and Biloxi at South Carolina, and the Haberlandt in Kentucky. Mineral-mixture supplement was self-fed in four experiments.

WEIGHTS OF PIGS USED

The desired average initial weight in most of these experiments was 100 pounds. There were deviations from this which could not be avoided, of course, and in the experiment conducted at the South

Carolina station the pigs were started immediately after weaning at an average of approximately 36 pounds. The range of beginning weights of the 62 hogs on which complete data are available was from 43 to 180 pounds. The average initial weight was 100.9 pounds.

Softness of Carcasses

The influence on firmness of this feed combination is clearly shown by Table 20, which summarizes the data on the 62 hogs referred to.

Table 20.—*Average weights, gains, feeding periods, gradings, and refractive indexes of back and leaf fats of 62 hogs fed soy beans plus a supplement of 2 to 2.5 per cent shelled corn*

Number of hogs	Grading (average and distribution)[1]	Initial weight	Gain	Days fed	Average daily gain	Slaughter weight	Refractive index	
							Back fat	Leaf fat
ALL HOGS								
62	S— 12 O, 39 S, 8 MS, 2 MH, 1 H	*Lbs.* 100.90	*Lbs.* 68.37	59.74	*Lbs.* 1.14	*Lbs.* 159.19	1.4617	1.4610
GAIN UNDER AVERAGE (68.37 POUNDS)								
26	S— 2 O, 21 S, 3 MS	99.42	43.04	51.00	.84	133.65	1.4615	1.4607
GAIN OVER AVERAGE (68.37 POUNDS)								
36	S— 10 O, 18 S, 5 MS, 2 MH, 1 H	102.00	86.67	66.05	1.31	177.64	1.4620	1.4612

[1] The initial letters in this column: O, oily; S, soft; MS, medium soft; MH, medium hard; and H, hard.

The average committee grading on all 62 hogs was soft, and refractive index of back fat 1.4617. As shown, only 3 of the 62 carcasses were graded hard or medium hard. All 3 were considerably heavier at the beginning than the average of the 62 pigs. Their average initial weight was 144 pounds as compared with 100.9 pounds for all.

Of the hogs which gained under and over the average gain (68.37 pounds) on this feed combination, the average gain in one group was practically double that in the other. It is of particular interest that with the greater gain there was a higher degree of softness. This is shown best by the average refractive indexes 1.4615 and 1.4620. Thus the basis for the conclusion below, which was released in the statement of July, 1924, is clearly shown.

Soy beans grazed or self-fed with a supplementary ration of 2.5 per cent of shelled corn with or without minerals self-fed produce soft hogs when the pigs are started on the feeds at approximately 100 pounds weight and make at least a moderate rate of gain through a feeding period of seven to eight weeks. Furthermore, the results have shown that the degree of softness of the carcass increases as the gain in weight of a hog on this feed combination increases.

Relation of Initial Weight and Gain to Softness of Hogs Fed Soy Beans and Corn Supplement

As in the case of peanuts and soy beans alone, the two factors, initial weight and gain, have a direct influence on the softness pro-

duced in the carcass. The 62 hogs upon which data were available were grouped as in the previous sections where these factors were discussed and the averages plotted in Figure 14.

Curves 1, 2, and 3 show the rate and degree of softening for increasing gains of the 70-pound, 100-pound, and 130-pound pigs. Compared with the results on soy beans alone much greater gains were required to produce oily carcasses. In fact, a gain of 44 pounds (which gave oily carcasses for all three groups in feeding soy beans alone) was not sufficient to produce oiliness, even in the 70-pound pigs.

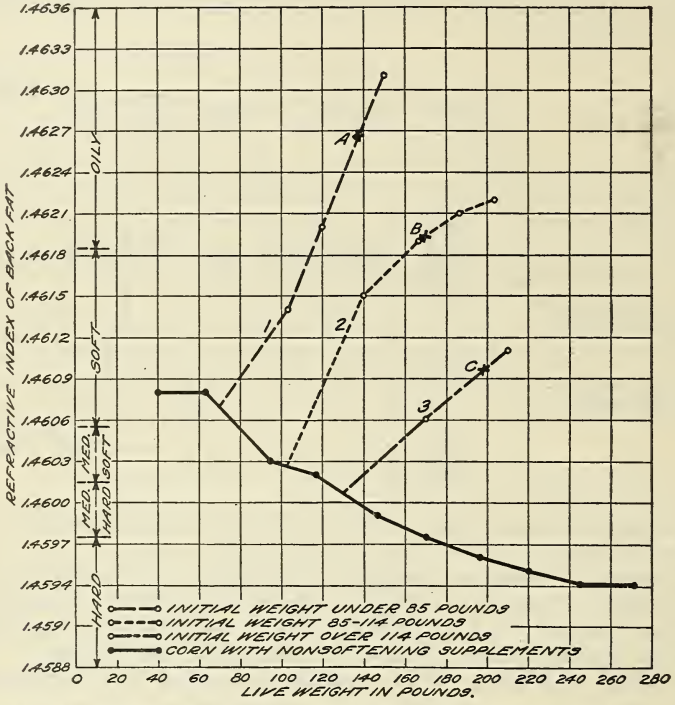

FIG. 14.—Curves showing the relation of initial weight and gain to the degree of softness in a ration of soy beans and 2 to 2.5 per cent corn

The average gain of all 62 hogs on soy beans and the 2 to 2.5 per cent ration of corn was 68.4 pounds. The softness of the three groups for such a gain is shown by points A, B, and C.

The decrease in the degree of softness with increasing starting weights when the gains are equal is very striking. From point A with a refractive index of 1.4627 (oily) there is a drop of 17 points to 1.4610 at point C.

FEEDING RESULTS WITH SOY BEANS GRAZED WITH A MEDIUM RATION OF SHELLED CORN

The feeding results from nine experiments with soy beans grazed with a medium ration (2 to 2.5 per cent) of shelled corn hand fed are combined in Table 21 and the discussion. The experiments were conducted at the Kentucky, Mississippi, and North Carolina stations and at the Beltsville farm during a four-year period, 1920 to

1923, inclusive. Three tests included in the preceding discussion of softness which developed on this combination of feeds are not to be considered here. In one of them, a South Carolina station test, the pigs had an average initial weight too low to justify the incorporation of feeding results with those from the nine experiments. The two others were Beltsville farm tests in which the beans (threshed) were self-fed in dry lot to a relatively small number of pigs.

The 100-pound initial-weight standard was followed as closely as possible in most of these experiments. The variation in average initial weights in the nine experiments was from 72 to 141 pounds. The general average of beginning weights was 109.09 pounds.

The method of feeding the soy beans in all experiments was to turn the pigs into the field after the bean seed had begun to mature. The pigs were weighed periodically, and from these weights as a basis the quantity of shelled corn to be fed per day was calculated. Thus, if a lot of pigs weighed 1,200 pounds on a certain weighing day it was fed 30 pounds of shelled corn daily until the next weighing day, when a recalculation was made. In no case did the period elapsing between weighing days exceed two weeks. It will be seen that by this method of calculation the shelled corn fed to the pigs daily averaged somewhat less than 2.5 per cent of their weight. Ten pigs in the 1923 test at the Beltsville farm had access to a mineral-mixture supplement in a self-feeder while in the soy-bean field. In all other experiments soy beans and corn were the only feeds supplied. Table 21 summarizes the feeding results from these nine experiments.

TABLE 21.—*Soy beans grazed and a medium (2 to 2.5 per cent) ration of shelled corn hand-fed*

Number of pigs used		127
Average number of days fed		51.06
Average initial weight	pounds	109.09
Average final weight	do	165.09
Average gain	do	56.00
Average daily gain	do	1.10
Corn consumed per 100 pounds gain	do	297.90
Average percentage of shelled corn (based on weight of pigs) consumed daily	per cent	2.39

The hogs received a mineral mixture in one experiment only, and in that case they gained at the rate of 1.25 pounds per hog daily, whereas those receiving only beans and corn in the same experiment made an average daily gain of 0.55 of a pound. This is probably a much greater difference than should be expected under average conditions. In all four Mississippi station tests the rate of gain exceeded the 1.25 pounds mentioned. The average gain made by the hogs in the test conducted at the North Carolina station was 1.17 pounds a day. The rates of gain in all lots fed at the Beltsville farm, except the one which gained 1.25 pounds per hog daily, were low.

There is a strong suggestion given by the data from these experiments and from those reported under section D that different varieties of soy beans or soy beans grown on different soils possess different feeding values for hogs. Further work must be done on this question. As an average 297.9 pounds of corn were consumed per 100 pounds gain in these tests. Since the data are incomplete and variable, no figures or estimates are given here on yields, costs of production, and consumption of soy beans. The reader is referred to Mississippi Circular 49 (*2*) for a full report of the feeding results from the tests conducted at that station. However, since 400 pounds

or more of grain or concentrated feed are usually required to produce 100 pounds of gain in dry lot, it is evident here that the bean crop consumed had a value equal to 100 pounds or more of grain for each 100 pounds of gain made.

It should be observed that the average per cent of shelled corn consumed daily was 2.39.

G. RICE POLISH WITH TANKAGE

Rice is a very important crop in several States. Those producing most of the rice in the United States are Arkansas, California, Louisiana, and Texas. In the process of preparing rough rice for human consumption the mills remove the hulls, bran, and polish. The bran and polish are used rather extensively in some sections of the country as feeds for livestock. Brewers' rice, another product of the mills often used in livestock feeding, will be discussed later in this bulletin. Rice polish is recognized as a valuable hog feed and will be considered first.

Nature of the Feeds

Table 22 shows the average composition of the rice polish used in the experiments, and for comparison the average composition of rice polish and dent corn.

Table 22.—*Composition of rice polish and dent corn*[1]

Feed	Water	Ash	Protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Rice polish used in experiments	10.34	6.28	11.91	1.93	57.46	12.08
Average, rice polish	9.40	5.00	12.10	2.10	61.70	9.70
Average, dent corn	12.90	1.30	9.30	1.90	70.30	4.30

[1] From Bureau of Chemistry, U. S. Department of Agriculture.

As shown by Table 22, rice polish on the average contains slightly more crude protein than corn, somewhat less nitrogen-free extract, and more than twice as much fat. The composition of the rice polish used in the experiments was very similar to the average with the exception of the fat, which was about 25 per cent higher. Whereas the average fat content of rice polish is twice that of corn, the rice polish used in these experiments contained three times as much fat as corn contains. This difference is considered significant in relation to softening. In addition to being present in relatively high percentage, the fat of rice polish is distinctly softening (see Table 2) in character. In Table 2 it will be observed also that rice fat has a higher iodine number and refractive index than peanut fat, indicating greater softening power than peanut fat.

The composition of rice polish is such that it is regarded as strictly a fattening feed. It may be considered, in fact, as a substitute for corn. Thus good hog-feeding practice demands that rice polish be supplemented with some protein concentrate, such as tankage.

All the experiments involving the feeding of rice polish were conducted at the Iberia Livestock Experiment Farm, Jeanerette, La.,

and at the Mississippi station. The former is a cooperative experiment station operated by the United States Department of Agriculture on land owned by the State of Louisiana. Five tests were carried out at the two stations during the four-year period 1921 to 1924, inclusive. The rice polish was self-fed, free choice, with tankage, and, with the exception of one lot in the Iberia farm experiment in 1921, on green oat or rye pasture in all cases. The one group of hogs referred to was fed in dry lot; no difference in firmness was noted. Two lots received 3.14 pounds of skim milk per hog daily throughout the experimental period. The data indicated no influence on firmness due to the milk, and the results are included with the others. A mineral-mixture supplement was self-fed in all tests.

Weights of Pigs Used

A 70-pound standard of initial weight was followed in connection with all experiments in which the influence of rice polish was studied. Considerable deviation from the desired weight occurred, the range of beginning weights being from 33 to 126 pounds for the 69 hogs on which complete data are available. The average initial weight of these hogs was 70.08 pounds.

Softness of Carcasses

To illustrate the distinct softening character of rice polish Table 23 is given.

Table 23.—*Averages of weights, gains, feeding periods, gradings, and refractive indexes of back and leaf fats of 69 hogs fed rice polish and tankage*

Number of hogs	Grading (average and distribution) [1]	Initial weight	Gain	Days fed	Average daily gain	Slaughter weight	Refractive index	
							Back fat	Leaf fat
ALL HOGS								
69	S.—{47 S, 16 MS, 3 MH, 3 H}	*Lbs.* 70.08	*Lbs.* 108.65	76.39	*Lbs.* 1.42	*Lbs.* 171.36	1.4609	1.4603
GAIN UNDER AVERAGE (108.65 POUNDS)								
36	MS.—{20 S, 10 MS, 3 MH, 3 H}	75.44	64.58	56.00	1.15	133.03	1.4611	1.4605
GAIN OVER AVERAGE (108.65 POUNDS)								
33	S.—{27 S, 6 MS}	64.24	156.73	98.64	1.59	213.18	1.4607	1.4601

[1] The initial letters in this column, S, soft; MS, medium soft; MH, medium hard; and H, hard.

Study of Table 23 shows that 63 of the total of 69 hogs were graded soft or medium soft by the committee. The 6 classed as hard and medium hard were, according to the refractive indexes, medium soft and soft. Their apparent firmness is probably explained by the fact that the temperature of the cooler was somewhat lower than normal while those particular hogs were being chilled and at the time of grading. This was unfortunate but unavoidable. The refractive index of back fat was 1.4609, which clearly classes the

69 hogs as soft. The table summarizes the data which supplied the basis for the following conclusion, which was included in the statement released in the summer of 1924.

Rice polish and tankage self-fed, free choice, on oat or rye pasture or in dry lot and with or without a small supplement of skim milk hand fed to pigs starting at 35 to 125 pounds weight and making gains of 30 pounds or more through a feeding period of from 8 to 15 weeks produce soft carcasses.

The second and third lines of data in Table 23 afford an opportunity for comparing the hogs which made less and more than the average gain (108.65 pounds) on rice polish. It will be observed that in the latter case the gain was more than double that in the former. Although the hogs in both groups class as soft or medium soft, it is of interest that the latter group had an average refractive index four points lower than the other. This suggests that after passing a certain weight or degree of finish there is a tendency for hogs fed rice polish to acquire gradually a lower degree of softness. Even if this observation is correct, it is questionable whether it would be practicable to attempt to produce hard hogs by long-continued feeding.

Relation of Initial Weight and Gain to Softening Effect of Rice Polish

The 69 hogs are grouped in Table 24 according to initial weights and gains to show the effects of these factors on the degree of softness in the carcass. They were first divided on the basis of initial weight into two groups, those under 70 pounds and those over 70 pounds. Each group was then divided into three subgroups based on gains of (1) 31 to 90 pounds, (2) 91 to 150 pounds and (3) 151 to 210 pounds.

Table 24.—*Averages on 69 hogs fed rice polish and tankage, grouped according to initial weights and gains*

Gain interval	Number of hogs	Grading (average and distribution)[1]	Initial weight	Gain	Days fed	Average daily gain	Slaughter weight	Refractive index: Back fat	Refractive index: Leaf fat
		INITIAL WEIGHT UNDER THE AVERAGE OF 70 POUNDS							
Pounds			*Pounds*	*Pounds*		*Pounds*	*Pounds*		
(1) 31 to 90	16	S—{13S, 2MS, 1MH}	54.8	56.7	56.0	1.01	107.0	1.4613	1.4607
(2) 91 to 150	10	S—{9S, 1MS}	50.1	135.6	90.3	1.50	189.7	1.4606	1.4600
(3) 151 to 210	10	S—{7S, 3MS}	52.0	169.5	105.0	1.61	208.5	1.4607	1.4602
		INITIAL WEIGHT OVER THE AVERAGE OF 70 POUNDS							
(1) 31 to 90	19	S—{7S, 7MS, 2MH, 3H}	91.4	69.2	56.0	1.24	151.8	1.4609	1.4603
(2) 91 to 150	8	S—{7S, 1MS}	85.3	132.0	91.0	1.45	214.5	1.4607	1.4600
(3) 151 to 210	6	S—{1MS, 5S}	82.8	189.5	105.0	1.80	255.2	1.4607	1.4600

[1] The initial letters in this column, S, soft; MS, medium soft; MH, medium hard; and H, hard.

Comparison of results given in the table shows the refractive index of 1.4613 for a gain of 56.7 pounds represented the maximum of the first group. The values of 1.4606 and 1.4607 for gains of 135.6 and 169.5 pounds, respectively, show that considerable hardening occurred following the early softening. In the second group a parallel change occurred, the refractive index values being (1) 1.4609, (2) 1.4607, and (3) 1.4607 for comparable gains.

There was a difference of four points in the refractive index between the low-gaining hogs in the two groups. Although there was a difference of 12.5 pounds in the gains, the difference in degree of softness was evidently due largely to that in starting weights. With gains over 100 pounds, however, there was practically no difference in the refractive index. These results may indicate that a drop had occurred to a fairly constant state of softness, with no variation attributable to either initial weight or gain. It seems more likely, however, that after passing a certain weight or degree of finish there is a tendency for the hogs gradually to become firmer. It is not possible to say just how far this hardening tendency may be carried or whether hard hogs can be produced by feeding for greater gains. Variations in initial weight such as discussed here appear to have no effect on the degree of softness for gains over 100 pounds.

The influence of initial weight when accompanied by gains under 100 pounds is noteworthy. As was the case with peanuts alone, soy beans alone, and soy beans plus a 2.5 per cent ration of corn, the rise in initial weights is accompanied by a lowering in the degree of softness for equal gains. In the case of the three rations just mentioned the difference held for high gains as well as low gains.

The following conclusion, included in the statement of July, 1924, was based on the data reported in this and preceding sections of this bulletin:

> Results have shown that when the softening feeds and feed combinations—peanuts or soy beans alone, soy beans supplemented with a 2.5 per cent ration of shelled corn, or rice polish and tankage (each with or without minerals)—are fed to pigs which have previously received no softening feeds there is a distinct relation between the degree of softness which develops and the weight at which the pigs are started on the feed. The degree of softness which develops in the pigs decreases as the starting weight increases, provided equal gains in weight are made and other factors are uniform. Whether the lighter pig of the higher degree of softness or the heavier pig of the relatively lower degree of softness will be hardened more readily by subsequent feeding of hardening feeds is still undetermined. Experiments to settle this question are now in progress.

Feeding Results with Rice Polish, Tankage, Mineral Mixture, and Green Oat and Rye Pasture

The feeding results from four experiments with rice polish and tankage self-fed, free choice, with mineral mixture on green oat and rye pasture, are combined in the following discussion and Table 25. The work was done at the Iberia farm and the Mississippi station from 1921 to 1924, inclusive. Only results from those lots of hogs self-fed rice polish, tankage, and mineral mixture, free choice, on green oat or rye pasture are summarized. The two kinds of pasture are considered here as having equal feeding values.

TABLE 25.—*Rice polish and tankage self-fed, free choice, with mineral mixture, on green oat and rye pasture*

Number of pigs used		72
Average number of days fed		62.94
Average initial weight	pounds	73.75
Average final weight	do	155.22
Average gain	do	81.47
Average daily gain	do	1.29
Feed consumed per 100 pounds gain:		
Rice polish	do	341.37
Tankage	do	25.37
Mineral mixture [1]	do	10.28
Total feed (not including pasture)	do	377.02

[1] Mineral mixture was self-fed in all tests, but in one test no record was kept of the quantity consumed. In this case the average of the three other experiments was taken as an estimate for the one test.

The average initial weights of the pigs in the different experiments varied through a fairly narrow range from 67 to 80 pounds. The average beginning weight of all 72 pigs fed in the four experiments was 73.75 pounds. Thus the standard which specified that 70-pound pigs should be used in these experiments was closely adhered to.

Table 25 gives a summary of the feeding results from these four experiments, and shows that a very satisfactory average rate of gain was made on this feed combination.

For some reason the 24 hogs fed in the one test at the Mississippi station did not gain so rapidly as those in the other tests. The average daily gain in the one case was 0.97 of a pound as compared with 1.16, 1.43, and 1.74 in the three Iberia farm experiments. In the one case there were marked symptoms, especially among the lighter-weight pigs, of intestinal irritation. The animals in the Mississippi station test made satisfactory use of their feed, however, the total feed consumed per 100 pounds gain being 367.10 pounds (not including pasture) as compared with 348.36, 359.49, and 414.76 pounds in the others. No attempt was made to measure the pasture requirement or utilization.

H. VARIOUS OILS ADDED TO BASAL RATIONS

The great importance of the fat in the feed in relation to the fat stored in the body of the hog has been emphasized in earlier sections of this bulletin. The apparent softening effects of the oils in peanuts, soy beans, rice polish, and corn have been pointed out. The degree of softening has been closely related to the quantity of oil present in the ration, at the same time giving due allowance to variations in the softening powers of the different oils. The brewers' rice ration, as is shown in the next section, containing approximately 1 per cent fat, gave the hardest carcasses; practically the entire source of the body fat in that case was in the carbohydrate and protein supply. The other feeds mentioned gave softer carcasses, depending on the quantity and quality of fat which each contained and the extent to which such fat was utilized as a source of body fat.

In order to obtain additional evidence on this subject some experiments were conducted at the United States Experiment Farm, Beltsville, Md., to study the effects of various oils added to a basal ration on the firmness of the body fat.

In a preliminary test involving three lots of two pigs each and averaging approximately 100 pounds at the start, corn oil and peanut oil were compared. The check lot received a ration of barley (89.5

per cent) and fish meal (10.5 per cent). The other two lots received rations containing the basal ration plus oil, made up to contain 85 per cent barley, 12 per cent fish meal, and 3 per cent oil. On slaughter, after a feeding period of 85 days, it was found that the oils had produced a distinct effect. The peanut and corn oil lots were medium soft, while the check lot was medium hard.

Some of the experiments were conducted during the spring of 1922 and others in the spring of 1923. The object in all the experiments was principally to determine the effect of adding definite quantities of oils to certain rations. In one case the question of the influence of the peanut proteins on formation of soft fat was considered.

Feeds Used and Methods of Feeding

The quantity of oil added to the basal ration in the preliminary experiment just discussed was felt to be somewhat low; hence in repeating these experiments the oil content was raised. Corn and tankage were used as a basal ration. This combination itself contains considerable oil (principally corn oil); therefore the results on the hog will be due to the naturally contained oil as well as the added oil. Nevertheless the effect of the latter can be determined by comparison with results on corn and tankage feeding.

The rations for the lots receiving corn and tankage as the basal mixture follow:

1. Corn meal, 84.5 per cent; tankage, 11.4 per cent; corn oil, 4.1 per cent.
2. Corn meal, 84.5 per cent; tankage, 11.4 per cent; peanut oil, 4.1 per cent.
3. Corn meal, 84.5 per cent; tankage, 11.4 per cent; soy-bean oil, 4.1 per cent.
4. Corn meal, 73.0 per cent; tankage, 15.5 per cent; corn oil, 11.5 per cent.

The corn, tankage, and oil were thoroughly mixed and hand-fed by lot.

Two additional lots received the following combinations.

5. Corn meal, 66.3 per cent; solvent-extracted peanut meal containing 1 per cent fat, 31.3 per cent; corn oil, 2.4 per cent.
6. Corn meal, 66.3 per cent; peanut meal (no hulls), 16.6 per cent; semisolid buttermilk, 44.4 per cent; peanut oil, 1.2 per cent.

The corn, peanut meal, and oil were mixed and hand-fed. The semisolid buttermilk in lot 6 was hand-fed separately after dilution with water. A mineral mixture was self-fed to all lots.

Table 26 gives the analyses of the feeds used.

Table 26.—*Composition of feeds used*

Feed	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Corn (experiments 1, 2, 5, 6)	15.03	1.07	8.84	2.06	69.03	3.97
Corn (experiments 3, 4)	14.90	1.31	8.46	1.90	69.86	3.57
Tankage (experiments 1, 2)	9.57	18.57	63.10			6.55
Tankage (experiments 3, 4)	7.40	22.90	57.12	3.24	3.64	5.70
Peanut meal (experiment 6)	7.21	6.26	30.15	18.52	30.04	7.82
Solvent-extracted peanut meal (experiment 5)	9.24	7.39	41.75	7.31	33.24	1.07
Semisolid buttermilk (experiment 6)	73.10	3.10	12.00		9.80	2.00

Weights of Pigs Used

In all lots except Nos. 4 and 5 the starting weights averaged approximately 100 pounds, with a range in weights of from 82 to 125 pounds. The pigs in lot 4 averaged 64 pounds and those in lot 5 averaged 124 pounds.

Influence of the Oils on the Carcasses

The averages of the results in the six lots are shown in Table 27.

Table 27.—*Weights, gains, grading, refractive indexes, and feed consumption on rations containing added oils*

Item	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
Special ration	Added corn oil 4.1 per cent	Added peanut oil, 4.1 per cent	Added soybean oil, 4.1 per cent	Added corn oil, 11.5 per cent	Peanut meal low in fat. Corn oil added	Peanut meal Buttermilk
Number of hogs	4	4	3	3	2	4
Days fed	79	79	90	84	70	79
Average initial weight ---pounds	102	97	101	64	124	104
Average gain ---do	130	122	135	115	86	132
Average daily gain ---pounds	1.65	1.54	1.50	1.37	1.23	1.67
Weight at slaughter ---pounds	226	215	220	174	205	230
Grading [1]	4MS	4MS	4S	30	2MS	2MS 1MH 1H
Refractive index:						
Back fat	1.4608	1.4603	1.4606	1.4632	1.4607	1.4601
Leaf fat	1.4599	1.4593	1.4599	1.4620	1.4599	1.4590
Feed consumption per 100 pounds gain:						
Corn ---pounds	355.2	323.5	323.7	188.9	311.8	191.5
Tankage ---do	47.9	43.6	43.7	40.1		
Peanut meal ---do					146.9	47.8
Semisolid buttermilk ---pounds						127.8
Corn oil ---do	17.1			29.8	11.2	
Soy-bean oil ---do			15.5			
Peanut oil ---do		15.7				3.2
Mineral mixture ---pounds	4.8	5.2	6.4	10.2	15.3	5.7
Total feed ---pounds	425.0	388.0	389.3	269.0	485.2	376.0
Oil and fat consumed calculated as contained in:						
Corn meal ---pounds	14.1	12.8	11.5	6.8	12.4	9.6
Tankage ---do	3.1	2.8	2.5	2.3		
Peanut meal ---do					1.5	3.7
Buttermilk ---do						2.6
Total oils consumed both added and naturally occurring (exclusive of tankage fat) ---pounds	31.2	28.5	27.0	36.6	25.1	19.1
Total oils, expressed as per cent of ration, exclusive of mineral mixture ---per cent	7.4	7.4	7.1	14.1	5.4	5.2

[1] The initial letters, O, oily; S, soft; MS, medium soft; MH, medium hard; and H, hard.

The results covering the six lots are in general uniform and consistent in the way of gains, gradings, refractive-index values, and feed consumption. Lot 4 shows the most noteworthy variation from the others in the quantity of feed consumed. The pigs in this lot were

the lightest of all, which may have been a factor, along with the nature of the ration, in producing such an exceptional utilization of the feed.

The data shown in the lower part of the table include some calculations on the quantities of oils consumed per 100 pounds gain and on the percentages of oil in the rations. Tankage fat was not included in the totals because of its close resemblance in composition to firm lard. These calculations are included to show the association of quantities of oils with the degrees of firmness.

The first three lots in which corn, peanut, and soy-bean oils were compared show marked effects from the addition of these oils. As evidenced by the refractive index, particularly, the corn oil and the soy-bean oil produced the softest fat. The values of 1.4608 and 1.4606, respectively, on the back fat indicate typically soft hogs. The refractive index of the back fat of the peanut-oil lot was 1.4603 (medium soft), suggesting that peanut oil is less softening than corn or soy-bean oil. From the iodine numbers and refractive indexes of soy-bean, corn, and peanut oils one would expect their softening power to be in the order named, from the greatest to the least.

The figures for the total oils consumed per 100 pounds gain and the percentages of oils in the rations indicate that such was essentially the case. Lot 3, the soy-bean-oil lot, shows a lower consumption and percentage than lots 1 and 2. Lot 1 (corn oil) showed the highest consumption, which would account for this lot being the softest.

A further increase in the corn-oil content was made in lot 4. The added oil was 11.5 per cent of the grain ration and the naturally contained oil was 2.6 per cent, making a total of 14.1 per cent. This is nearly double the quantity in lot 1, but is not quite one-half that in a ration of whole, unshelled peanuts. The pigs started on this experiment at the weight of 64 pounds, which probably permitted softness to develop more rapidly. Typical oily carcasses were produced, the back fat having a refractive index of 1.4632. The total consumption of corn oil per 100 pounds gain was only 36.6 pounds, as compared with 31.2 pounds in lot 1. The differences in starting weight and in feed utilization, however, explain the wide difference in softness. The figures on feed consumption show what can be produced from the feeding of such quantities of oil to lightweight pigs.

These results furnish the basis for an interesting comparison. The brewers' rice and tankage ration, containing less than 1 per cent fat, gave a refractive index of 1.4584; corn and tankage, with 3.5 to 4 per cent oil, a value of 1.4596; the combination in lot 1, with 7.4 per cent oil, gave 1.4608; whereas that in lot 4, with 14.1 per cent oil, gave 1.4632.

The ration in lot 5 was made up of corn meal, solvent-extracted peanut meal containing approximately 1 per cent fat, and corn oil enough to make the total oil content equal to that usually found in a mixture of corn 2 parts and hydraulic-pressed peanut meal 1 part. The added oil was 2.4 per cent of the total ration, that in the corn meal 2.7 per cent, and in the peanut meal 0.3 per cent, making a total of 5.4 per cent. The total oil consumption of 25.1 pounds was somewhat higher than the average for corn-peanut-meal feeding. The two hogs in the test were graded medium soft and had a refractive index of 1.4607. This value is slightly higher than the average corn-peanut-

meal hogs. Thus, with the oil supplied almost entirely as corn oil, softening occurred as in the original mixture of corn and peanut meal.

Lot 6 was planned to determine whether the peanut protein contributed to the formation of soft fat. Whole peanuts, as well as the mixture of corn 2 parts and peanut meal 1 part, have a high-protein content with a correspondingly narrow nutritive ratio, especially when the peanut meal used is made from shelled nuts. In the experimental lot the protein content was kept the same as in the corn-peanut-meal ration. One-half the peanut meal was replaced by semisolid buttermilk containing the same quantity of protein as the replaced meal. The protein mixture of the ration was thus altered and the possibility of an influence of the peanut protein on fat formation lessened. A sufficient quantity of peanut oil was added to keep the oil content the same as in the original mixture. The four hogs composing the lot gave some variation in the degree of softness. Two were graded medium soft, one medium hard, and one hard. The refractive index averaged 1.4601. Considering the fact that the hogs made very rapid gains and were slaughtered at a weight of 230 pounds, with the fact that the total oil consumption (19.1 pounds) was comparatively low, the slightly firmer condition of the carcasses can be accounted for and the results taken as showing the peanut protein to have no direct effect on softness. Additional evidence from unpublished results supports this conclusion.

I. BREWERS' RICE WITH TANKAGE

Brewers' rice is one of the recognized classes of milled rice. It is composed largely of broken, cracked, shrunken grains, and contains not more than 25 per cent of whole kernels. Being a low-class product, the price is often such that it can be fed to hogs with profit. Brewers' rice is not a widely known feed, but is fed to a considerable extent, with very satisfactory results, in the rice-growing sections. Wherever known it is recognized as a valuable hog feed.

Nature of the Feed

Table 28 shows the composition of the brewers' rice used in the tests, and for comparison the average composition of this feed and of dent corn.

Table 28.—*Composition of brewers' rice and dent corn* [1]

Feed	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Brewers' rice used in experiment	12.49	0.56	7.32	0.45	78.12	1.06
Average brewers' rice	12.40	.60	7.30	.40	78.50	.80
Average dent corn	12.90	1.30	9.30	1.90	70.30	4.30

[1] Figures on brewers' rice from nutrition laboratory, Animal Husbandry Division, Bureau of Animal Industry; on corn from Bureau of Chemistry U. S. Department of Agriculture.

The outstanding differences between the two feeds as shown by Table 28 are the higher nitrogen-free extract and lower fat content of the brewers' rice. Furthermore, the crude-protein per cent in brewers' rice is somewhat lower than in corn. The two sets of

analytical results on this feed agree very closely. It is apparent that brewers' rice, like corn, is strictly a fattening feed. The fat content is remarkably low, and it is that fact which is of particular interest here. Whereas corn is a low-fat and high-carbohydrate feed, and for those reasons is hardening in its influence, brewers' rice contains only about one-fifth as much fat and considerably more carbohydrates. The composition of brewers' rice indicates a decidedly hardening influence. Two experiments involving the feeding of brewers' rice, both conducted at the Iberia Livestock Experiment Farm in 1921 and 1922, are considered here. In both cases tankage and mineral mixture were self-fed, free choice, with the brewers' rice on green-oat pasture. In one test an additional supplement of 3.14 pounds of skim milk per hog daily was fed. No influence of the skim milk on firmness could be detected from the data, and the results are combined with those from the other test.

Weights of Pigs Used

Pigs having initial weights approximately the same as those fed in connection with the rice-polish work were used in these experiments. The range of initial weights of the 19 hogs on which complete data are available was from 36 to 88 pounds, inclusive. The average initial weight was 60.37 pounds.

Firmness of Carcasses

The influence of brewers' rice on firmness of hog carcasses is shown very clearly in Table 29.

Table 29.—*Averages of weights, gains, feeding periods, gradings, and refractive indexes of back and leaf fats of 19 hogs fed brewers' rice and tankage*

Number of hogs	Grading	Initial weight	Gain	Days fed	Average daily gain	Slaughter weight	Refractive index	
							Back fat	Leaf fat
19	Hard (all)	*Pounds* 60.37	*Pounds* 177.21	92.84	*Pounds* 1.91	*Pounds* 238.68	1.4584	1.4580

Table 29 is a summary of results from a much smaller number of hogs than is discussed in any of the preceding sections of this bulletin. The pronounced consistency of these results, however, together with the strong indications received from the other lines of feeding in which brewers' rice has been used, make the drawing of a conclusion here appear justified. All the 19 hogs were classed as hard by the grading committee; in fact, the carcasses were much firmer than are produced in corn feeding. The average refractive index of back fat was 1.4584, the lowest average observed to date for any feed used in these investigations. The lowest individual result was 1.4579. This average refractive index (1.4584) at a live weight of 238.68 pounds at slaughter is 10 points lower than that of corn-fed hogs (1.4594) at a similar weight. (See fig. 8 for corn-fed hogs.) In all other work in which there has been opportunity to compare results from hogs fed brewers' rice and corn the indications have been that the hogs fed brewers' rice were distinctly the firmer.

These facts are responsible for the conclusion below, which was included in the statement issued in 1924:

> Brewers' rice and tankage self-fed, free choice, on oat pasture with or without a small supplement of skim milk hand fed to pigs starting at approximately 60 pounds weight and making gains of 150 to 200 pounds throughout feeding periods of 12 to 15 weeks produce, in the usual case, extremely hard hogs, in fact of a degree of firmness distinctly greater than that occurring in corn-fed hogs.

Brewers' rice, as shown above, is a low-fat feed. The percentage of fat is so small, in fact, as to be almost negligible. Thus the fat stored by hogs fed brewers' rice is very largely synthetic, or has its origin mainly in the carbohydrates of the feed. The fact that an extreme degree of firmness is produced by this feed supports strongly the hypothesis that carbohydrates are mainly responsible for the deposition of firm fat in the hog body.

Feeding Results with Brewers' Rice, Tankage, and Mineral Mixtures, Pasture, Etc.

Two lots of hogs were fed brewers' rice at the Iberia Livestock Experiment Farm,[13] one in 1921 and the other in 1922. Each lot was composed of 12 pigs. Both were self-fed brewers' rice, tankage, and mineral mixture, free choice, on green-oat pasture, and one lot received in addition an average of 3.14 pounds of skim milk per hog daily.

The range of initial weights of the 24 pigs was from 36 to 88 pounds, and the averages in the two lots were 65.25 and 60.50 pounds, respectively.

Table 30 gives summaries of the feeding results from the two lots of hogs.

Table 30.—*Brewers' rice, tankage, and mineral mixture self-fed, free choice, on green-oat pasture with and without a small supplement of skim milk*

Item	Lot 1. Brewers' rice, tankage, mineral mixture, oat pasture	Lot 2. Brewers' rice, tankage, mineral mixture, skim milk, oat pasture
Number of pigs used	12	12
Average number of days fed	103. 25	84. 00
Average initial weight, pounds	65. 25	60. 50
Average final weight, do	242. 00	234. 58
Average gain, do	176. 75	174. 08
Average daily gain, do	1. 71	2. 07
Feed consumed per 100 pounds gain:		
Brewers' rice, do	361. 39	333. 22
Tankage, do	11. 88	3. 97
Mineral mixture, do	3. 68	. 67
Skim milk, do		151. 41
Total feed (not including pasture), do	376. 95	489. 27

The results from the two lots are shown in one table for convenience. There are scarcely hogs enough in each lot to make comparison of results reliable. Furthermore, the two lots were not fed concurrently, but in different years. Thus there is the possibility of difference in

[13] Results reported in Louisiana Planter (*20*).

conditions which would not have existed had the lots been fed at the same time.

It should be observed that the two lots were started on experiment at about the same average initial weights and that the average final weights show a difference of less than 8 pounds. Of particular interest is the fact that the average daily gain in each lot was high, 1.71 pounds in one case and 2.07 pounds in the other. Either of these is a satisfactory figure, especially when the lengths of the feeding periods are taken into account. Exclusive of pasture, 376.95 and 489.27 pounds of feed, the latter including 151.41 pounds of skim milk, were required to produce 100 pounds of gain in the two lots. These figures also can be considered as highly satisfactory, and the high feeding value of brewers' rice for hogs is further shown.

J. PEANUT MEAL WITH CORN

The manufacture of peanut oil has become an important industry in recent years in several sections of the South. Each year many thousands of bushels of peanuts pass through the oil mills. The principal by-product of the manufacture of peanut oil is peanut meal. Good-quality Spanish variety peanuts in the shell yield, in fact, approximately twice as much meal as oil. Generally speaking there are two recognized grades of peanut meal—low protein and high protein—in which the proportion of shells is the main controlling factor. Peanut meal is a valuable livestock feed and is used rather extensively in hog production, especially in the territory within moderate shipping distance of the mills. The meal to be considered first in this section is the high-protein grade, or that containing a minimum of shells, and it is combined with 5 parts of corn meal.

Nature of the Feeds in High-protein Experiments

The composition of the feeds used, and for comparison the average composition of peanut meal and corn, are given in Table 31.

Table 31.—*Composition of peanut meal (shell free) and dent corn*

Feed	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
Peanut meal (shell free) used in experiment [1]	*Per cent* 7.16	*Per cent* 7.29	*Per cent* 46.59	*Per cent* 8.03	*Per cent* 22.09	*Per cent* 8.84
Average peanut meal (shell free) [2]	6.20	4.90	49.30	6.30	22.50	10.80
Dent corn used in experiment [1]	10.88	1.28	8.92	1.79	72.41	4.72
Average dent corn [2]	12.90	1.30	9.30	1.90	70.30	4.30

[1] Analyses made by Alabama station.
[2] From Bureau of Chemistry, U. S. Department of Agriculture.

It should be observed in Table 31 that peanut meal (shell free) contains a high percentage of protein and a moderately high percentage of fat. The protein content classes it as a supplementary feed to be used with low-protein concentrates, such as corn. The fat content considered in conjunction with the character of peanut fat (see Table 2) opens the question as to the influence on firmness of peanut meal when fed in various feed combinations. As shown by Table 31, the peanut meal fed in this work was fairly typical of this grade of meal. The corn was fully up to standard.

One experiment conducted at the Alabama station provided the results reported here. Five lots of 12 hogs each were fed. All lots received a mixture of ground corn 5 parts, and shell-free peanut meal, 1 part, in self-feeders in dry lot. In addition four of the five lots had mineral-mixture supplement in self-feeders. The feeding period was 68 days.

Weights of Pigs Used

Complete data are available on 57 of the 60 pigs started on test. The extremes of the range of initial weights of the 57 pigs were 48 and 113 pounds, and the average weight when the test began was 79.25 pounds.

Firmness of Carcasses

Table 32 is given below to show the distribution of the committee gradings of the 57 hogs and certain pertinent facts relative to the animals placed in each grade.

Table 32.—*Distribution of gradings and weights and gains by grades*

	Hard	Medium hard	Medium soft	Soft
Number of hogs	21	10	16	10
Average initial weight, pounds	87.52	83.40	71.12	70.70
Average final weight, do	227.62	186.80	158.81	150.90
Average gain, do	140.10	103.40	87.69	80.20

Table 32 above shows that the 57 hogs were rather well distributed throughout the four grades. Some variation in average initial weights may be observed. The difference in initial weight between the hard or medium hard as compared with the soft or medium soft is noticeable. This difference, however, is deemed insufficient, when considered in connection with the average total gain of the hogs in the different grades, to have a major bearing on the results. The variation in firmness is considered to be due to the variation in gain. It appears clear, in other words, from study of the table that the gain, and therefore the final weight, and the firmness vary directly.

The relation between gain made on this combination of feeds and the firmness of the hogs is apparently so important that a detailed study of it has been made for the purpose of presenting the results graphically (fig. 15).

The curve shown with the dotted line represents results from the 57 hogs fed the mixture of ground corn 5 parts and shell-free peanut meal 1 part. It will be noted that they started on experiment at an average weight of approximately 79 pounds and with an average refractive index near 1.4606. As the weight and gain increased from the starting point, there was a gradual lowering of the refractive index or increase in the degree of firmness. According to the curve, at about 150 pounds the hogs had acquired the medium-hard condition and at 195 pounds had become strictly hard. The low point of refractive index reached was 1.4593.

The curve for hogs fed corn and nonsoftening supplements (fig. 8 in section A) is referred to here for the purpose of comparison. The marked similarity between the two curves is noteworthy. It is believed that the indication of a slightly softer condition, up to

about 203 pounds, of the hogs fed peanut meal has no particular significance; nor has the fact that the carcasses appear to have been slightly firmer from 203 pounds to 241 pounds. It seems most probable that at any certain weight the difference in firmness, with few exceptions, between hogs fed the two feed combinations will be negligible. The above facts show the basis for another of the conclusions released in July of 1924. The conclusion follows:

The mixture of corn meal (5 parts) and peanut meal (hull free, 1 part) self-fed with or without supplementary minerals to pigs starting at approximately 80-pound weight and making gains of approximately 100 pounds through a feeding period of 9 to 10 weeks produces, in the usual case, hard or medium hard hogs.

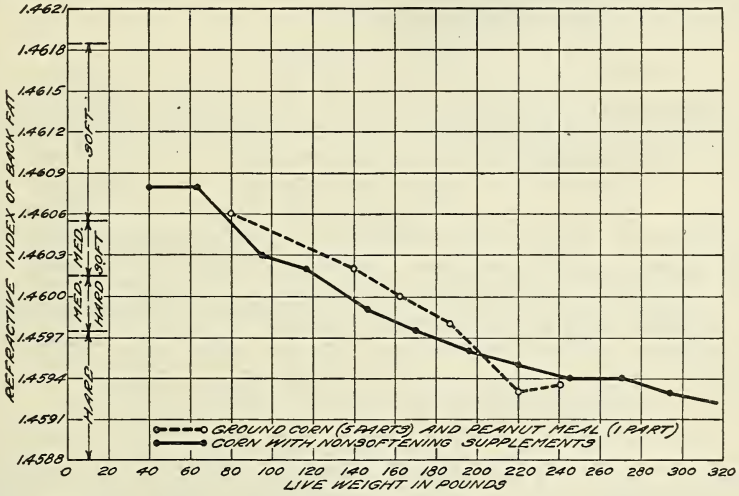

FIG. 15.—The progressive hardening on a mixture of ground corn, 5 parts, and peanut meal, 1 part

As previously stated, the high-protein content of peanut meal classes it as a supplementary feed for use with highly carbonaceous feeds, such as corn, rice polish, brewers' rice, and grain sorghums. Naturally in the United States it is used mainly as a supplement to corn. Obviously in studying the combination of peanut meal and corn from the soft-pork standpoint a primary question for determination is the maximum proportion of peanut meal that can be used

TABLE 33.—*Composition of mixture, ground corn 5 parts and shell-free peanut meal 1 part, fed to five lots of hogs at Alabama station*

Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
Per cent 10.26	*Per cent* 2.28	*Per cent* 15.20	*Per cent* 2.83	*Per cent* 64.02	*Per cent* 5.41

under any certain conditions without producing soft hogs. The fat content of the mixture, of course, is the principal controlling factor. The composition of the mixture fed in this work is shown in Table 33.

Although the composition in general of the feed mixture as shown by Table 33 is of interest and indicates satisfactory feeding value for the class of hogs fed, the fat content should be especially noted. This, it may be observed, was 5.41 per cent, approximately three-fourths of which was corn fat and the remainder peanut fat. Both, as shown in Table 2, are regarded as softening fats. Thus, in view of the firmness of the hogs produced on this feed combination, it must be concluded that the fat was present in insufficient quantity to exert a softening influence. With a larger proportion of peanut meal in the mixture, thereby increasing the fat percentage, an entirely different result may be obtained. It is believed, in fact, that a relatively small increase from the 5.41 per cent may produce hogs decidedly different in degree of firmness.

Feeding Results

Feeding results from four of the five lots fed at the Alabama station in 1923–24 on ground corn (5 parts) and shell-free peanut meal (1 part) mixed, self-fed with mineral mixture in dry lot, and discussed in the preceding section on firmness, are presented in the following. The four lots of 12 pigs each received mineral-mixture supplement of varying composition in the different lots and produced nearly uniform results. The fifth lot was not supplied with mineral mixture, and in view of a marked difference in results is not included with the others in the summary of feeding results. The mineral mixtures self-fed in the four lots were composed as follows:

Mineral mixtures fed to four lots at Alabama station

No. 1		No. 3	
Charcoal	1 part.	Calcium carbonate	2 parts.
Calcium carbonate	1 part.	Steamed bone meal	1 part.
Salt	1 part.	Salt	1 part.
No. 2		**No. 4**	
Calcium carbonate	2 parts.	Calcium carbonate	5 parts.
Acid phosphate	1 part.	Steamed bone meal	2 parts.
Salt	1 part.	Salt	2 parts.
		Tankage	1 part.

The variation in initial weights of the 48 pigs fed in the four lots was from 39 to 113 pounds, inclusive. The average weight of the pigs at the beginning of the test was 78.98 pounds.

Table 34 gives a summary of the feeding results obtained from the 48 hogs fed in the four lots.

TABLE 34.—*Ground corn (5 parts) and shell-free peanut meal (1 part) mixed, self-fed with mineral mixture in dry lot*

Number of pigs used		48
Average number of days fed		66.88
Average initial weight	pounds	78.98
Average final weight	do	193.90
Average gain	do	114.92
Average daily gain	do	1.72
Feed consumed per 100 pounds gain:		
Ground corn	do	284.46
Peanut meal (shell free)	do	56.89
Mineral mixture	do	7.12
Total feed	do	348.47

Table 34 shows a very satisfactory rate of gain under the conditions. The feed consumption per 100 pounds of gain is of particular interest. A total of 284.46 pounds of ground corn, 56.89 pounds of peanut meal, and 7.12 pounds of mineral mixture were required as an average for each 100 pounds of gain made by the pigs. This is a total of 348.47 pounds of feed. It seems probable that this is a better utilization of the feed than should be expected under average conditions. However, it indicates the high feeding value of shell-free peanut meal when used with certain minerals as a supplement to corn.

Additional experiments were conducted in which peanut meals, both the high protein or shell-free and low protein or shell-containing grades, were fed. The work was done at the Alabama station and the United States Experiment Farm, Beltsville, Md. A mixture of peanut meal 1 part and ground corn 2 parts was used in most of these experiments, and results from that feed combination are here reported. No noteworthy difference in influence upon firmness exerted by the two grades of meal when fed in this combination has been observed, and they will be considered together in this discussion.

Nature of the Feeds

Although peanut meals made from both shelled and unshelled nuts were used in this work, most of the hogs received the latter grade. The composition of each grade varied considerably in the different experiments. This was particularly true of the fat content, which varied from 7.3 per cent to 10.8 per cent in the shell-free meal and from 5.8 per cent to 10.9 per cent in the shell-containing meal. Analyses of a large number of samples of each grade made by the Bureau of Chemistry show that such ranges of fat percentages are not unusual. The results from this work, however, do not justify presentation according to the composition of the meals or mixtures used in the different experiments. In other words, the relation between the firmness of the hogs produced and the composition of the mixture fed in the different experiments is not sufficiently clear or direct to warrant showing results according to the latter. Further work may develop differences in results which can be attributed to difference in grade of peanut meal or composition of the 1 to 2 mixture, but no attention will now be given to those possible but probably minor factors.

Weights of Pigs Used

Complete data pertaining to firmness are available on 213 hogs fed in 16 experimental lots. The extremes of the range of initial weights of the 213 hogs were 45 and 170 pounds. A number of the earlier experiments were run with pigs having an average initial weight of approximately 100 pounds. In certain later trials, however, the initial weight was varied to study its possible influence upon firmness. The average initial weight of the 213 hogs was 100.95 pounds.

Variation in Firmness of Carcasses

Table 35 is given to show the distribution of the committee gradings with the average weights, gains, and refractive indexes of back and leaf fats for the hogs of each grade.

TABLE 35.—*Distribution of gradings and weights, gains, and refractive indexes, by grades*

Item	Grading				
	Hard	Medium hard	Medium soft	Soft	Oily
Number of hogs in each grade	46	35	47	82	3
Per cent of hogs in each grade	21.60	16.40	22.10	38.50	1.40
Average initial weight.....pounds	115.37	103.66	109.98	87.38	78.00
Average final weight.....do	217.76	206.46	213.60	185.16	204.00
Average total gain.....do	102.39	102.80	103.62	97.78	126.00
Average daily gain.....do	1.28	1.21	1.27	1.01	1.17
Average refractive index:					
Back fat	1.4599	1.4601	1.4604	1.4607	1.4607
Leaf fat	1.4591	1.4593	1.4593	1.4598	1.4597

Table 35 shows by the distribution of the hogs in the several grades that the feed combination under investigation had a marked tendency to produce neither hard hogs nor soft hogs. A total of 38 per cent were hard or medium hard and 62 per cent were medium soft, soft, or oily. It seems worthy of note that the soft and oily hogs had comparatively low average initial weights. There was 16.28 pounds difference between those of the soft and medium hard classes, the latter being the next highest in order. The initial weights considered in connection with the gradings and refractive indexes suggest the possibility of initial weight being a factor influencing firmness. No conclusion to that effect, however, can be drawn from these data.

Figure 16 illustrates the changes in firmness which occurred during the progress of the feeding. This figure represents the same 213 hogs discussed above. The hogs were grouped according to gains as in previous sections, the averages obtained and then plotted. The basal curve shows the progressive hardening on corn and nonsoftening supplements (fig. 8) with the curve for the corn and peanut-meal hogs starting from the basal curve at an initial weight of 100 pounds.

It is seen from Figure 16 that the first 40 pounds gain made by the hogs resulted in considerable softening. Associated with the gain was a rise of 5 points in refractive index, or a change from medium soft to distinctly soft. Passing 140 pounds weight, there was a gradual hardening effect, at least to 210 pounds. The rise between 210 and 230 pounds, however, is not considered significant. It was probably due to individuality, which, on account of the smaller number of animals represented toward the end of the curve, had an opportunity to show itself. It is probable that in a strictly representative case the curve would come down more and more gradually as the 200-pound mark is approached, and then practically flatten out with little, if any, hardening from 200 to 260 pounds weight. Of noteworthy interest is the fact that the curve does not cross the line into the medium-hard class at any point.

Compared with Figure 8, and even with Figure 15, the differences are very striking. Evidently the higher oil content of the ration of peanut meal 1 part, and corn 2 parts, due, of course, to the higher oil content of peanut meal than that of corn, has been responsible for the greater softening which occurred. Additional data on the relation of oil and of protein to this feed combination were presented in section H, lots 5 and 6.

The 1 to 2 combination of peanut meal and ground corn appears to be a critical mixture of the two feeds, so far as influence on firmness is concerned. It seems to occupy a place on the line between softening and hardening feeds. Under these circumstances it would appear that factors aside from feeds probably have an opportunity to show clearly their influence and are responsible for the degree of firmness produced. There may be conditions under which consistent results can be obtained, but they have not been determined. The feeder is therefore cautioned not to use this combination unless he is willing to accept any consequences that may come from offering soft hogs to the markets.

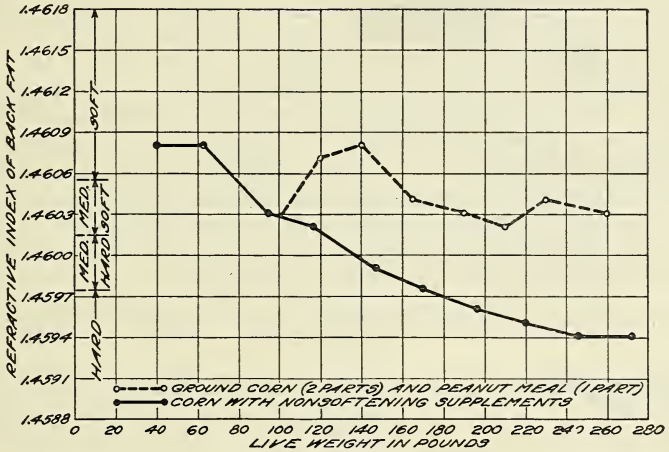

FIG. 16.—Relation of gain to firmness of hogs fed a ration of peanut meal, 1 part, and ground corn, 2 parts

FEEDING RESULTS WITH SHELL-CONTAINING AND SHELL-FREE PEANUT MEAL 1 PART AND GROUND CORN 2 PARTS

Both shell-containing and shell-free peanut meals were fed with corn in this work at the Alabama station and the United States Experiment Farm. Twelve lots containing 177 hogs received the former grade of meal, three lots containing 39 hogs the latter grade. The mixture was self-fed in dry lot. Mineral-mixture supplement was self-fed in all lots included in the summary. The results for the two meals are given in separate tables.

The variation in average initial weights of the pigs fed shell-containing meal in the 12 lots was from 73 pounds to 140 pounds, the general average of the 177 pigs being 103.74 pounds. The low and high average initial weights among the three lots fed shell-free meal were 85 pounds and 103 pounds, with a general average of 94.46 pounds for the 39 pigs.

Table 36 summarizes the feeding results obtained from the 177 hogs self-fed the shell-containing meal in the 1 to 2 mixture.

TABLE 36.—*Mixture of shell-containing peanut meal 1 part and ground corn 2 parts, self-fed in dry lot*

Number of pigs used		177
Average number of days fed		87.40
Average initial weight	pounds	103.74
Average final weight	do	205.26
Average gain	do	101.52
Average daily gain	do	1.16
Feed consumed per 100 pounds gain:		
Mixture of peanut meal 1 part and ground corn 2 parts	do	499.59
Mineral mixture	do	10.11
Total feed	do	509.70

The average daily gain was 1.16 pounds per hog. The average final weight, 205.26 pounds, shows that the hogs receiving the shell-containing meal were fed to a satisfactory market weight.

The feed consumed per unit of gain was rather high. In 1 of the 12 lots summarized no record of mineral-mixture consumption was obtained. The average quantity consumed per 100 pounds gain in the 11 other lots was considered, for the purposes of this summary, as applying also to the 1 lot. These figures on feed utilization suggest that the feeding value of shell-containing peanut meal as a supplement to corn for fattening hogs is not extraordinary.

Table 37 summarizes the feeding results obtained from the 39 hogs self-fed the shell-free meal in the 1 to 2 mixture.

TABLE 37.—*Mixture of shell-free peanut meal 1 part and ground corn 2 parts self-fed in dry lot*

Number of pigs used		39
Average number of days fed		88.64
Average initial weight	pounds	94.46
Average final weight	do	207.90
Average gain	do	113.44
Average daily gain	do	1.28
Feed consumed per 100 pounds gain:		
Mixture of peanut meal 1 part and ground corn 2 parts	do	406.58
Mineral mixture	do	8.70
Total	do	415.28

A total of 406.58 pounds of the 1 to 2 shell-free mixture and 8.70 pounds of mineral mixture was consumed for each 100 pounds of gain made. No record of mineral-mixture consumption was obtained in one of the three lots. The average quantity consumed per 100 pounds gain in the other lots was considered as applicable in all three, and so figured for the above table. A total feed consumption of 415.28 pounds per 100 pounds gain is very satisfactory. Considering the results given in Tables 37 and 34, it seems evident that shell-free peanut meal is a valuable supplement to corn for fattening hogs.

OTHER QUESTIONS UNDER INVESTIGATION

Certain experiments have been reported in the preceding pages and the conclusions expressed represent only a portion of the results obtained. Among other questions being studied are the following:

The possible softening effects of other feeds than peanuts, soy beans, and rice polish, including rice bran, chufas, mast, alfalfa when used extensively, and soy-bean-oil meal. The questions for determination with peanut meal and soy-bean meal are the proportions of hardening feed which must be fed to counteract the softening influence.

Brewers' rice, sweet potatoes, barley, blackstrap molasses, buttermilk (semisolid), wheat middlings, and cottonseed meal in relation to their hardening qualities. The last four mentioned are regarded only as supplemental feeds.

Soy beans as a supplement to corn for fattening hogs in dry lot, on pasture, and when grown with corn and hogged down.

As the use of proper mineral supplements materially increases the degree to which some feeds are utilized by hogs, do they have an indirect influence on firmness?

The influence of variation in initial weight on the requirements for hardening by subsequent feeding of hogs fed softening feeds, when other factors are uniform.

The influence of variation in gain on softening feeds on the requirements for subsequent hardening.

The maximum length of time at an average rate of gain during which each softening feed or feed combination can be fed and permit the hog to be subsequently hardened within a practical period.

The influence upon firmness of variation in the type of the pig.

Is thrift as measured by rate of gain related to the degree of firmness or to the requirements for hardening? And is there any relation between firmness and rate of gain among uniformly thrifty pigs when the rate of gain is varied by the quantity of feed supplied?

Does firmness (or softness) in the sire or dam have an influence on that of the pig, and if so, to what extent?

The relation of breed, sex, and parasitic infestation of the liver to firmness.

The relative shrinkage of hard, soft, and oily hogs from live weight to cooked products.

SUMMARY

The soft-pork problem is one of long standing in the United States. Formerly it was regarded as sectional and recognized as important only in peanut-producing localities. Developments of recent years, however, have firmly established it as a nation-wide problem.

The carcasses of soft hogs remain soft when chilled at the temperature and for the length of time commonly employed in commercial meat-packing plants. Those of hard hogs acquire a satisfactory degree of firmness under the same conditions. Oily hogs differ from soft only in degree of softness, occupying the lowest position in the scale of physical grades.

The undesirable characteristics of the products from soft and oily hogs place them at a disadvantage on the market, resulting in live-hog price discriminations. Thus it is apparent that the soft-pork problem concerns a number of classes of people, including producers, packers, dealers, and consumers.

The firmness of a hog carcass or its products depends almost entirely on the firmness of the fat. Thus the soft-pork problem is fundamentally a problem in fat metabolism. The variations in the firmness of the fat are due to the differences in its composition. The soft fat contains a higher amount of unsaturated fatty acids than the hard fat. The methods employed in these investigations in determining this difference consist in grading the chilled carcasses according to a scale of physical grades and analyzing the fat for the refractive index. This value, giving as it does a close measure of

the amount of unsaturated fatty acids, agrees very closely with the physical grade.

Feed, being the only source of body fat, is the outstanding factor among the causes of soft pork. Other factors are often mentioned and must be considered in a complete study of the problem, but can exert only secondary influences. Soft pork is peculiarly a fat problem, because, on the one hand, the quantity of fat in the hog feeds used in this country varies widely, although usually oily in nature while, on the other hand, body fat always constitutes a very large proportion of the weight of the finished hog. Thus a situation exists in which there is an exceedingly heavy demand in the animal body for fat for storage in the tissues and an extremely variable supply of fat in the feeds available for deposition. Since it is a well-established fact that feed fats in general are carried through the digestive and assimilative systems and deposited in a form closely resembling the original, the quality (softening or hardening) and quantity of fat in a ration become exceedingly important factors. In fact, it may be concluded that the soft fat of a hog is caused by soft fat in the feed.

When high-fat feeds, such as peanuts and soy beans, are fed as the main or entire portion of the ration the fat is sufficient to account for all or a large proportion of the body fat. In other cases with lower percentages the feed fat is only a partial source of the body fat, the remainder being synthesized from carbohydrates and probably from protein when the latter is present in sufficient amount. It is evident that the fat formed from carbohydrates and protein is always materially harder than that derived from the fats of peanuts, soy beans, rice, and corn, all of which are strikingly softening. Thus it may be concluded that the wider the ratio of feed fat (softening in character) to carbohydrates and protein entering into fat deposition the firmer is the body fat stored.

It is evident from the results obtained to date that the desired or standard grade of firm pork in this country is produced on a ration containing a small quantity of softening oil (corn), which apparently is blended in with the fat made from carbohydrates and protein by the animal. The hardening of the fat of a hog previously rendered soft by the feeding of the softening rations has always occurred with an increase in the quantity of synthesized fat and a relative decrease in that of the feed fat used for storage.

The relative amounts of gain made (or, to be more explicit, of fat stored) by the hogs on different feeds have an important bearing upon the degree of firmness (or softness) developed. The stage of maturity, of course, has a marked influence upon the rate of fat deposition at any particular time. In reporting results in this bulletin particular attention has been given to the actual weights and gains of the hogs rather than to the length of time on experimental feed. The latter has been reported with the average daily gain figures, so that for practical purposes comparisons on a time basis may be made.

The progress made in solving the soft-pork problem in its more practical aspects has come through the definition and establishment of certain basic facts associated with the normal process of growth and fattening in the hog. These facts pertain to (1) the relative softening or hardening properties of the feeds concerned in the desired combinations and the reasons for such properties; (2) the

influence of the stage of development or size at which a given ration is fed; and (3) the influence of gains (weight and estimated fat) on the rations. The conclusions which have been published, together with supplemental facts, were based largely on such interpretation of results. They are as follows:

(1) There is a direct relation between immaturity and softness in pigs. When pigs are fed on ordinary feed combinations which are not unusually low in fat content, such as corn and tankage, or corn, middlings, and tankage, on pasture or in dry lot, and slaughtered at a weight of approximately 100 pounds or less, they are in the usual case soft.

(2) Hogs fed corn and tankage gradually become firmer as they mature or take on weight and finish. While hogs fed in this way are usually soft at 100 pounds or less, the hardening is progressive, so that when slaughtered at approximately 175 pounds or more they are in the usual case hard.

Corn, middlings, and tankage have a similar effect. Fish meal can replace tankage in either combination.

(3) Peanuts grazed or self-fed with or without supplementary minerals for a period of 60 days to pigs starting at approximately 100 pounds in weight produce soft (or oily) carcasses. It is impossible to produce hard carcasses by feeding corn and tankage or corn and cottonseed meal to such soft hogs for a subsequent period of 60 days, although the soft hogs are made firmer by subsequent feeding of hardening feeds.

(*a*) The average gain made by the hogs while on peanuts was approximately 1 pound a day and on the hardening ration about 1⅓ pounds per day. The average refractive index of all peanut-fed hogs was 1.4619, and of those fed corn with nonsoftening protein supplements for 88 days subsequent to peanuts for 55 days was 1.4605. The average grading of the latter was soft, but comparison of the refractive indexes (1.4619 versus 1.4605) indicates the hardening which occurred.

(*b*) Hardening on corn and nonsoftening supplements proceeds more slowly than softening on peanuts. With pigs starting at approximately 100 pounds initial weight it appears to require about three times as much gain on corn and nonsoftening protein supplements as previously made on peanuts to produce hogs of a moderate degree of firmesss.

(4) Soy beans grazed or self-fed alone or with minerals self-fed through a period of seven to eight weeks to pigs starting at approximately 100 pounds weight and making gains of 40 to 50 pounds produce soft carcasses. Furthermore, the results have shown that the degree of softness of the carcass increases as the gain in weight of a hog on this feed increases.

(5) Soy beans grazed or self-fed alone or with minerals self-fed to pigs starting at approximately 100 pounds weight and making at least a moderate rate of gain through a period of seven to eight weeks will not produce firm carcasses, even though a subsequent gain in weight has been made by the pigs on corn and tankage equal to that previously made on soy beans.

(6) Soy beans grazed or self-fed with a supplementary ration of 2.5 per cent of shelled corn with or without minerals self-fed produce soft hogs when the pigs are started on the feeds at approximately 100 pounds weight and make at least a moderate rate of gain through a feeding period of from seven to eight weeks. Furthermore, the results have shown that the degree of softness of the carcass increases as the gain in weight of a hog on this feed combination increases.

(7) Rice polish and tankage self-fed, free choice, on oat or rye pasture or in dry lot and with or without a small supplement of skim milk hand fed to pigs starting at from 35 to 125 pounds weight and making gains of 30 pounds or more through a feeding period of 8 to 15 weeks produce soft carcasses.

(8) When the softening feeds and feed combinations, peanuts or soy beans alone, soy beans supplemented with a 2.5 per cent ration of shelled corn or rice polish and tankage (each with or without minerals), are fed to pigs which have previously received no softening feeds, there is a distinct relation between the degree of softness which develops and the weight at which the pigs are started on the feed. The degree of softness which develops in the pigs decreases as the starting weight increases, provided equal gains in weight are made and other factors are uniform. Experiments are in progress to determine whether the lighter pig of the higher degree of softness or the heavier pig of the relatively lower degree of softness will be hardened more readily by subsequent feeding of hardening feeds.

(9) Brewers' rice and tankage self-fed, free choice, on oat pasture with or without a small supplement of skim milk hand fed to pigs starting at approximately 60 pounds weight and making gains of from 150 to 200 pounds through feeding periods of from 12 to 15 weeks produce, in the usual case, extremely hard hogs, in fact of a degree of firmness distinctly greater than that occurring in corn-fed hogs.

(10) The mixture of corn meal 5 parts and peanut meal (hull free) 1 part self-fed with or without supplementary minerals to pigs starting at approximately 80 pounds weight and making gains of approximately 100 pounds through a feeding period of from 9 to 10 weeks produces, in the usual case, hard or medium hard hogs.

The mixture of corn meal 2 parts and peanut meal 1 part fed with or without supplementary minerals can not be depended on to produce consistently either hard or soft hogs (when finished) under usual conditions. There may be conditions under which consistent results can be obtained, but they have not been determined. In view of the present knowledge the feeder is cautioned not to use this combination unless he is willing to accept any consequences that may come from offering soft hogs to the market.

The conclusions given in this bulletin represent only a portion of the results actually obtained during the progress of this work. Many other questions involved in the soft-pork problem are being studied and a great mass of valuable data pertaining to them has already been obtained. Still other questions are recognized as requiring study as time and facilities permit. Further conclusive results will be published as progress of the work justifies.

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